MAY 1960

VOL. 52 • NO. 5

Journal

AMERICAN WATER WORKS ASSOCIATION

Signs of the "good old days" at Coalinga, where demineralization plant now makes homebrew do

In this issue:

DEVELOPMENTS IN DESALINIZATION
Strobel, Sieveka, Sandell, Bradt, Lof, Cary, Ongerth, Phelps

NEW JERSEY DEVELOPMENT
Shanklin

WATER REUSE AND PUBLIC HEALTH
Berger

OHIO RIVER SYNDET CONTENT
Weaver, Coughlin

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Chang, Woodward, Kabler

UNDERGROUND WASTE DISPOSAL
Task Group Report

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ECONOMIC ASPECTS OF WELL STIMULATION
Koenig

CORROSION EFFECTS ON CAST-IRON PIPE
Hamilton

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Byerrum, Anwar, Hoppert

POROUS-PLATE FILTER BOTTOMS
Roe

TASTES OF METALS IN WATER
Cohen, Kamphake, Harris, Woodward

JOURNAL STYLE MANUAL
Editorial Statement

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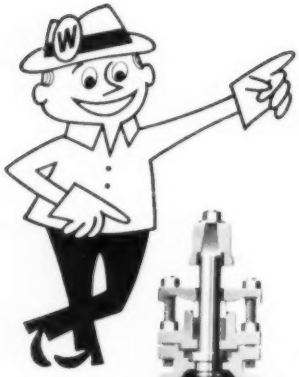

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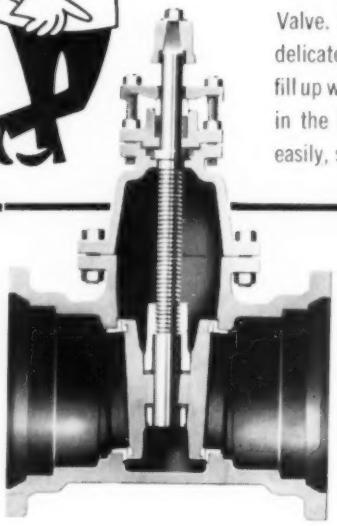

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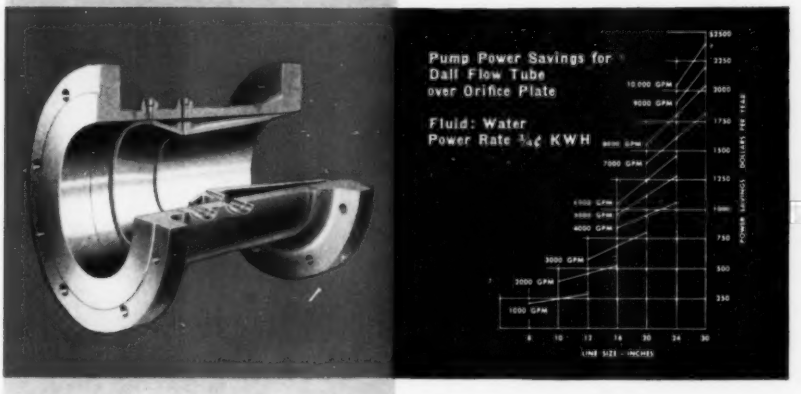

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AWWA SECTIONS

Spring 1960

Jun. 2—New Jersey Section, at Riverton Country Club, Riverton. Secretary, A. F. Pleibel, Dist. Sales Mgr., R. D. Wood Co., 683 Prospect St., Maplewood.

Jun. 14–17—Pennsylvania Section, at Hilton Hotel, Pittsburgh. Secretary, L. S. Morgan, 413 First National Bank Bldg., Greensburg.

Fall 1960

Sep. 7–9—South Dakota Sec., Watertown.

Sep. 12–14—Kentucky-Tennessee Sec., Knoxville, Tenn.

Sep. 14–16—Virginia Sec., Virginia Beach.

Sep. 14–16—New York Sec., Whiteface.

Sep. 21–23—Michigan Sec., Traverse City.

Sep. 21–23—North Central Sec., St. Paul, Minn.

Sep. 25–27—Missouri Sec., Jefferson City.

Sep. 28–30—Wisconsin Sec., Madison.

Oct. 6—Connecticut Sec., Hamden.

Oct. 9–12—Alabama-Mississippi Sec., Birmingham, Ala.

Oct. 16–19—Southwest Sec., Galveston, Tex.

Oct. 19–21—Iowa Sec., Des Moines.

Oct. 19–21—Chesapeake Sec., Washington, D. C.

Oct. 20–22—New Jersey Sec., Atlantic City.

Oct. 24–27—Rocky Mountain Sec., Colorado Springs, Colo.

Oct. 25–27—California Sec., Long Beach.

Oct. 26–28—Ohio Sec., Columbus.

Nov. 9–11—North Carolina Sec., Winston-Salem.

Nov. 13–16—Florida Sec., Fort Lauderdale.

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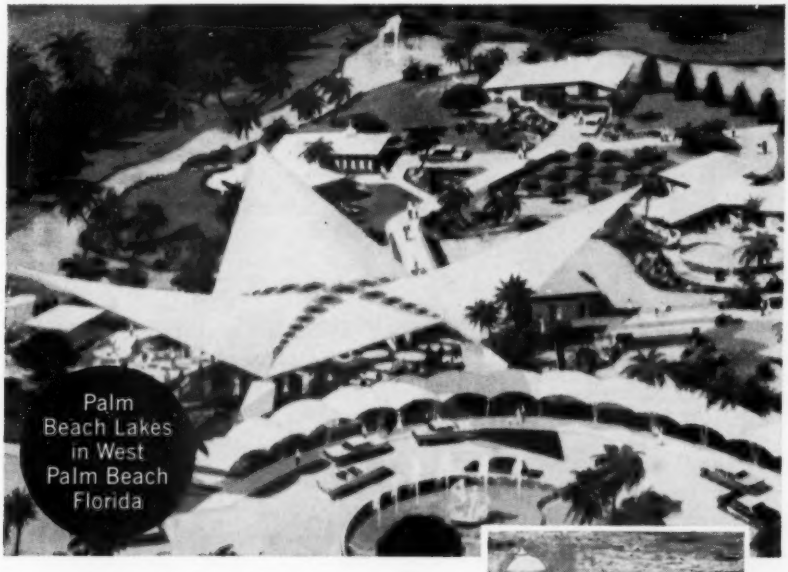

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Coming Meetings

(Continued from page 6)

OTHER ORGANIZATIONS

May 9–13—2nd Southwestern Metal Exposition & Congress, American Society for Metals, with other technical groups, State Fair Park & Sheraton Hotel, Dallas, Tex. Write: Allan Ray Putnam, Managing Director, Metals Park, Novelty, Ohio.

Jun. 1–3—5th Appalachian Underground Corrosion Short Course, West Virginia University, Morgantown, W.Va. Write: John H. Alm, Rm. 605, 2 Gateway Center, Pittsburgh 22, Pa.

Jun. 6–8—Rudolfs Memorial Research Conference, Rutgers University, New Brunswick, N.J. Subject of the conference is principles of collodial behavior and application to water sanitation. Write: H. Heukelekian, Chairman, Dept. of Sanitation, Rutgers Univ., New Brunswick, N.J.

Jun. 8–11—National Society of Professional Engineers, Statler Hotel, Boston, Mass.

Jun. 20–Jul. 1—Course on "Aquatic Biology for Engineers," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

Jun. 20–24—Summer general meeting, AIEE, Atlantic City, N.J.

Jun. 26–Jul. 1—ASTM, Chalfonte-Haddon Hall, Atlantic City, N.J.

Aug. 15–19—Course on "Recent Developments in Water Bacteriology," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

Aug. 22–27—Seventh Internation Conference on Coastal Engineering, Kurhaus, Scheveningen, The Hague, Netherlands. Write: J. W. Johnson, Engineering Field Station, Bldg. 159, Univ. of California, Richmond 4, Calif.

Aug. 23–25—Symposium on water quality data collection and utilization, R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Director, 4676 Columbia Pkwy., Cincinnati 26, Ohio.

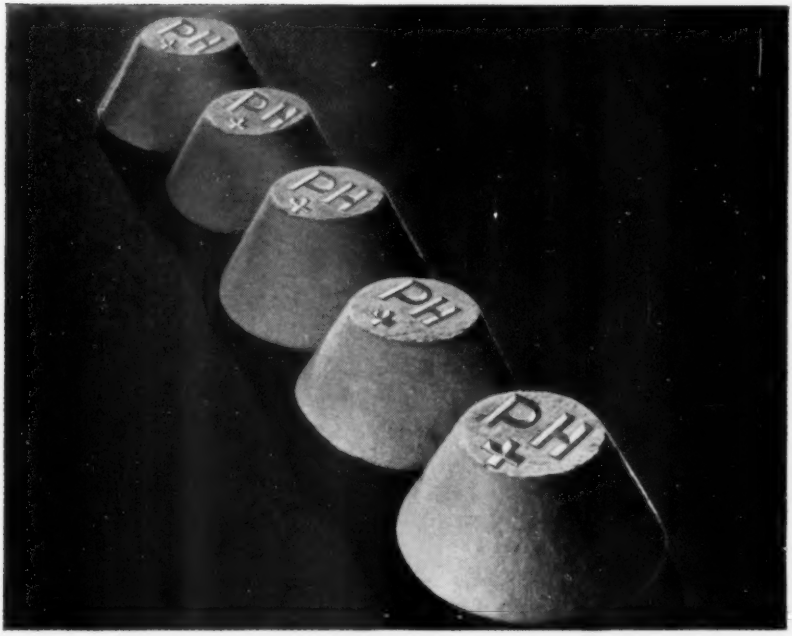
Sep. 18–22—NEWWA, Queen Elizabeth Hotel, Montreal, Que.

Oct. 2–6—WPCF, Convention Hall, Philadelphia, Pa.

Oct. 10–14—Fall general meeting, AIEE, Chicago, Ill.

Oct. 17–21—48th annual National Safety Congress, Chicago, Ill., with sessions on industrial safety scheduled for Conrad Hilton, Pick-Congress, Sheraton Towers, Morrison, and La Salle hotels. Write: R. L. Forney, Secy., National Safety Council, 425 N. Michigan Ave., Chicago 11, Ill.

Nov. 27–Dec. 2—Annual meeting, ASME, Statler Hilton Hotel, New York, N.Y.



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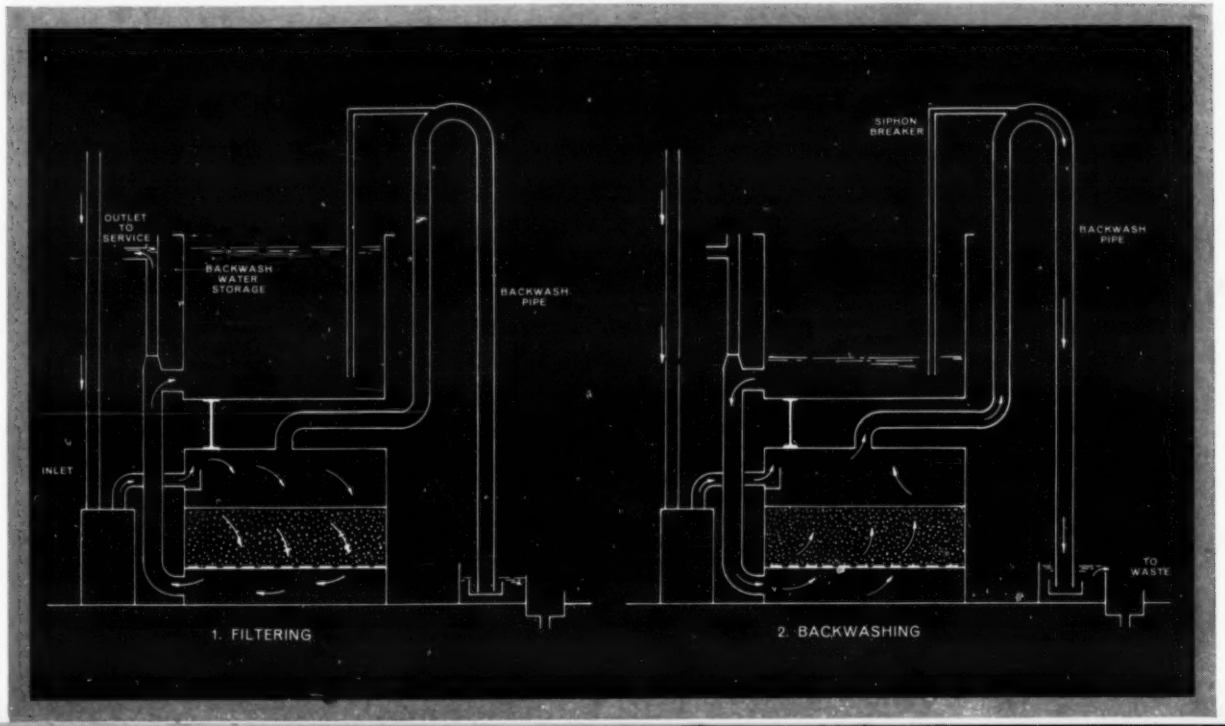

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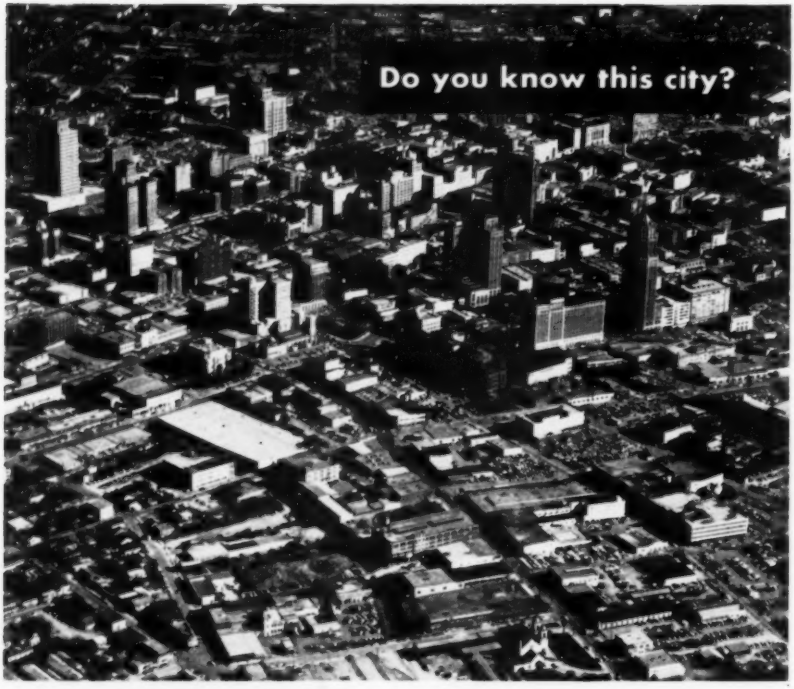

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serve the citizens of...

San Antonio . . . city of Alamo fame, growing to meet the demands of its dynamic citizens and economy.
Here, De Laval water works pumps have been providing vital water requirements with increasing reliability—as they have in most major American cities for over half a century.
De Laval makes water works pumps with capacities ranging up to 100 million gallons per day to meet all water works requirements.

Write for your copies of De Laval Bulletins 1004 and 1005 giving data on these pumps.

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PROTECT STEEL, CONCRETE... REASONABLY

You can do the job efficiently with these two cold-applied Allied Chemical Coal Tar Coatings . . .

"Allied Chemical" Coal Tar Paint #110 goes on as easily as oil-base paints, protects against weather, mold, corrosive vapors, moisture too severe for ordinary paint. This low-cost coating dries to a shiny black finish.

"Allied Chemical" 34Yc Coating #134 dries to a heavy duty, resilient film as thick as 6 or 8 coats of ordinary paint. Recommended for all surfaces exposed to extreme moisture or to very corrosive vapor and spillage. Withstands temperatures from —20° to +160°F. Excellent, for example, on load-bearing structural steel.

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Though we've changed the name from Barrett Protective Coatings to Allied Chemical, you receive the same famous protection in pipeline coatings—proved and improved for three generations.

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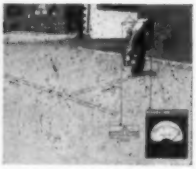
Leak Survey Instrument and Pipe Locator

The transistorized "MASTER" Leak Detector—Pipe Finder Combination is the first dual purpose instrument with separate and independent leak detector and pipe finder circuits. Now you can have two instruments in one without any compromise in performance. The "MASTER" Leak Detector—Pipe Finder incorporates the very latest advances in electronic construction and circuitry in addition to having an exceptionally long battery life. An ideal instrument for any Water Department.

Finding a leak under pavement

Locating a leak at the valve

Location of dead ends



Locating a service

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Place your next order with POLLARD

It's from POLLARD It's the Best in Pipe Line Equipment

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NON-CLOG SEWAGE AND TRASH PUMPS... a Fairbanks, Morse first, are matchless in mechanical construction and long-life, low-cost quality! Designed to handle unscreened sewage, storm water, and industrial wastes, our Non-Clog Pumps are the products of 75 years experience in making better pumps for municipalities.

More City Halls

There is a Fairbanks, Morse pump to meet all the needs of any municipality, regardless of size or location. Vertical type pumps ideal for wet or dry pit installation. Horizontal type pumps for direct drive.

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ANGLE FLOW PUMPS... proved big volume performers because of wide, unobstructed passages through impeller and volute, are ideal for sewage and storm water. Rugged construction insures low-cost operation! Standard sizes (vertical or horizontal) available in horse powers and capacities for every

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requirement. Vertical units designed for dry or wet pit service. Horizontal pumps mounted either on soleplates or steel baseplates can be powered by direct-connected motor.

WE ALSO MANUFACTURE peak efficiency Tur-

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bine Pumps for municipal water systems, single and Multi-Stage Centrifugals for booster stations... and Fire Pumps. For more information, write:

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Another Eimco-Process design innovation . . .

An annular sludge trough is a key feature of the Type CSPA Oxidator. By positioning the trough outside the aeration zone, both the sludge raking distance and the sludge holding time are shortened and deep, uniform aeration is possible without sludge dilution.

Want good treatment on both low and high flows?

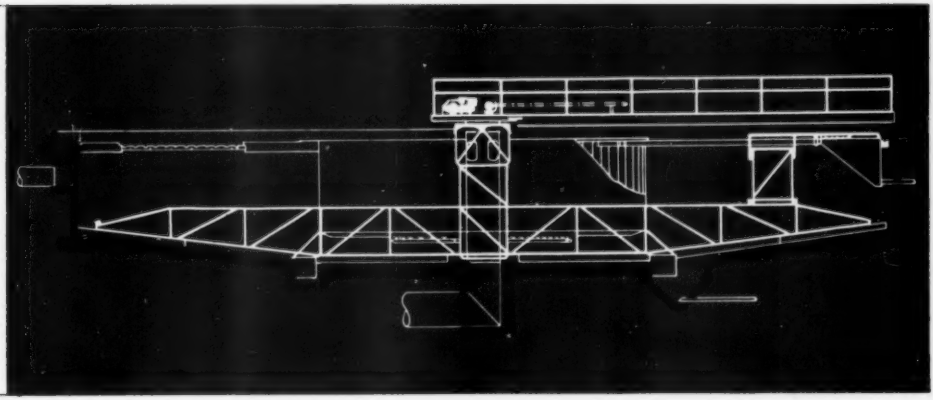
THE OXIDATOR®

WAS DESIGNED

FOR YOU!

If you are concerned with widely varying flows, or if you are designing for ultimate high capacity yet need good treatment at present low flows, the Oxidator is meant for you. This economical intermediate treatment unit combines aeration, flocculation and sedimentation in a single tank to give high removals at near the cost of primary treatment.

Thorough aeration minimizes scum formation and keeps the influent fresh. Light organics are



quickly flocculated and efficiently removed. And . . . the exclusive annular sludge trough design permits obtainment of a concentrated sludge in a short detention period.

Whether for consideration on an immediate problem or for future reference, you should know about the improved Oxidator. Detailed information is available from any of our nationwide representatives or you may wish to write directly to us in San Mateo.

B-574

. . . another outstanding installation

90 ft. dia. Eimco- Process Oxidator with annular sludge trough in operation at Ponca City, Oklahoma. Consulting Engineers— Pate Engineering Company, Tulsa, Oklahoma.

THE EIMCO CORPORATION

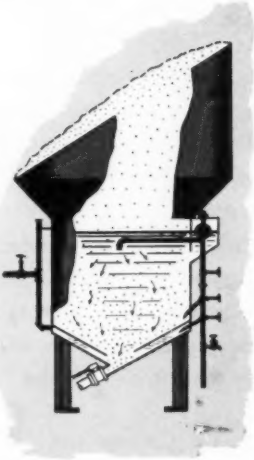
Process Engineers Division

420 Peninsular Avenue
San Mateo, California

BRINE FILTRATION

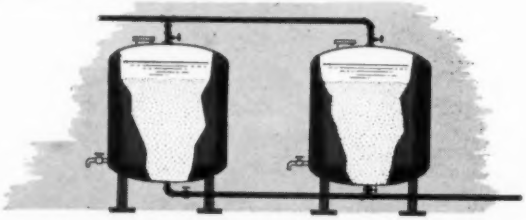
How it can affect design of water softening installations

Whichever filter medium you select—sand, gravel or anthracite, undissolved crystals of rock salt—this much is clear: dissolver design and regeneration expenses are bound to be affected. For example: Provision should be made for periodically removing the accumulated insolubles from the filter bed. Design of filters should incorporate the necessary cleanout facilities. And a brine-filtration setup that performs well with one type of salt may be inadequate with another.



The growing amounts of brine in use in today's large-capacity water softening installations complicate filtration problems. That's why treatment plant designers and builders are turning more frequently to International Salt Company. With over 50 years of experience and continuing research in all phases of salt handling and brine production, International can suggest many new and practical ideas in connection with salt purchase, storage and dissolving for regenerating ion exchangers. There is no charge for this service.

Service and research are the extras in STERLING SALT



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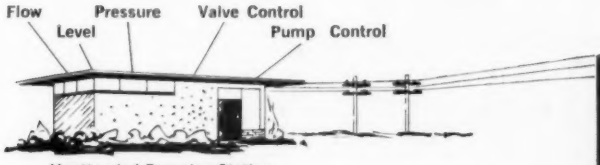
FLUIDICS* AT WORK



Unattended Pumping Station

Cut costs, improve efficiency—automate your present water system with Simplex Orthoplex Supervisory Control

ORTHOPLEX SYSTEM can pay for itself during the first year of operation.

ORTHOPLEX assumes the responsibility for automatically controlling remote pumping stations, control valves, elevated tanks, reservoirs – FREES PERSONNEL FOR MORE IMPORTANT JOBS.

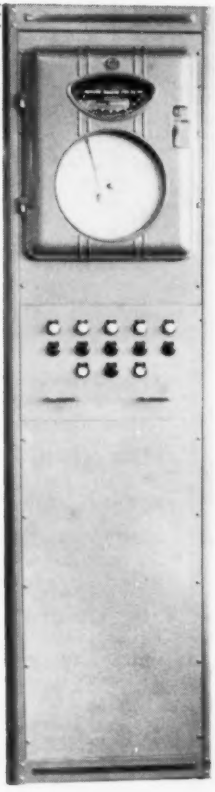
ORTHOPLEX can be installed to operate with most existing flow- and level-sensing devices without change or with the addition of new low-cost devices.

IMPROVED DESIGN reduces maintenance to the minimum by the elimination of all vacuum tubes, motorized timers and motorized sequence switches.

AS MANY AS 29 CHANNELS over a single pair of wires—private or telephone.

FOR COMPLETE INFORMATION, send us your requirements.

*FLUIDICS is the Pfaudler Permutit program that integrates knowledge, equipment and experience in solving problems involving fluids.



Central Control Station

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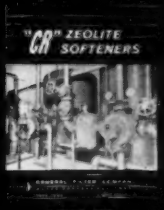
NEW BULLETINS ON TREATMENT OF WATER, SEWAGE & INDUSTRIAL WASTE

AERATORS

FILTER PLANTS

CLARIFIERS



ZEOLITE SOFTENERS

AERATORS—Describes aerators for oxidation of dissolved iron and manganese, and for elimination of odors and gases. Explains and pictures forced draft aerators, pressure aerators and atmospheric aerators.

FILTER PLANTS—Lists problems of untreated water and offers solutions. Explains and pictures four basic water treatment methods for elimination of turbidity, minerals, gases, organic matter, and for pH correction.

CONTRAFLO UPFLOW CLARIFIERS—Pictures and describes five basic contraflo types for water softening and clarification. Explains application for industrial waste neutralization and recovery processes.

"CR" ZEOLITE SOFTENERS—Illustrates design and construction details of ion-exchange softeners for hardness removal; tells how to select proper units. Explains various types of regeneration equipment.

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Efficient Coagulation of Surface or Well Water—Effective in lime soda-ash softening—Adaptable in treatment of all industrial applications.

SEWAGE TREATMENT
Coagulates over wide pH ranges and provides efficient operation regardless of rapid variations of raw sewage—Very effective for conditioning sludge prior to vacuum filtration or drying on beds.

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Excellent Taste and Odor Control
Increased Filter Runs
Coagulation Over Wide pH Range
Rapid Floc Formation Turbidity Removal
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Bacteria Removal Ease of Operation
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For a complete list of our products see our inserts in CHEMICAL WEEK BUYER'S GUIDE, Pages 173-176 or CHEMICAL MATERIALS CATALOG, Pages 551-554.

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by Fischer & Porter Co.
manufacturers of
precision controls

3400 Series Chlorinator

1960 ushers in the decade of scientific chlorination control. Fischer & Porter has expanded its famed diaphragm principle . . . proved in thousands of installations and adopted as standard throughout the world. The new 3400 series offers you many advanced design features including a *single stack* chlorine gas regulator providing life-long dependability, complete operational safety, and adaptability to any type of automatic control.

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First with a Single Stack Regulator

- Ruggedly constructed of heavy, durable, corrosion-resistant parts, the unique single stack regulator packs dozens of new features into the least possible space.
- The exclusive isolating diaphragm prevents even *traces* of moisture from feeding back from the water ejector into the precision functioning parts of the chlorinator.
- The rugged construction of the unitized stack minimizes service and repair. Frail piping between components is eliminated. Parts within the stack are neither sealed nor inaccessible. The stack regulator provides high accuracy and reproducibility even under the widely varying chlorine gas and water supply pressures.

First in Safety and Serviceability

- Controlled vacuum conditions throughout protect plant personnel. Any interruption of ejector vacuum instantly closes the chlorine gas inlet valve and, if desired, actuates alarm signals.
- Inert materials of construction have been carefully selected to assure long life and safety.
- Operating parts are housed within an attractive two-tone fiberglass cabinet. The color is an integral part of the cabinet completely eliminating painting or other maintenance.

First in Flexibility

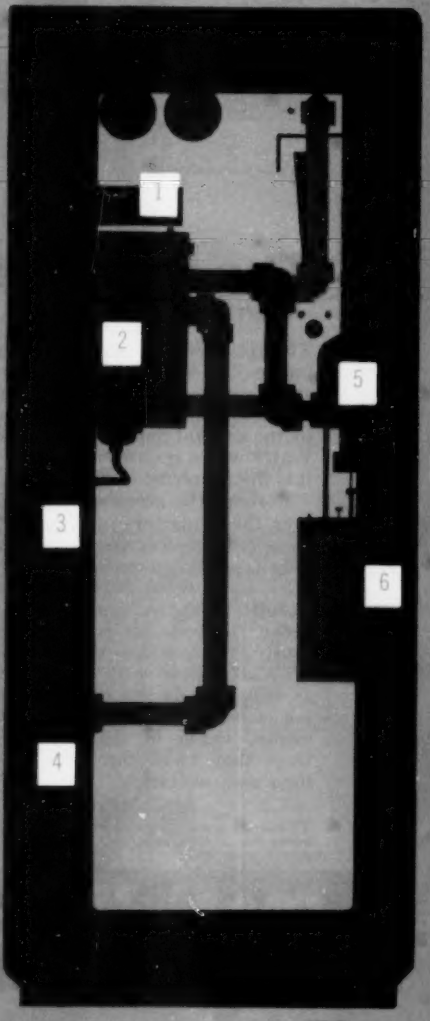
- Both floor and wall-mounted models are available to meet every operating or installation requirement. Each chlorinator is equipped with a precisely calibrated F&P 20:1 range flowmeter. Capacities range from 0.1 to 2000 pounds per day of chlorine gas. Integral or remote ejectors may be selected. Manual-automatic conversion is readily accomplished at your plant.

First in Control—
the Controlomatic Chlorinator

- Controlomatic models of the new line accept electric, pneumatic, or vacuum signals from any type of metering device, and accurately feed chlorine according to proportional, start-stop, program, multiple rate, or residual control requirements. Fischer & Porter can supply the complete system . . . including metering instruments and analyzers as well as the chlorinator. The unique Vis-I-Flow proportioning valve is safety-enclosed and yet visible! You can check performance and accuracy at all times.

GET COMPLETE FACTS! Contact your local Fischer & Porter Representative now, or, write for your copy of free Catalog 70C3400. Fischer & Porter Co., Department 12, Warminster, Pennsylvania.

1 Dosage Controller
2 Single Stack Regulator
3 Chlorine Input & Heater
4 Ejector
5 Vis-I-Flow Valve
6 Automatic Proportioning Control



FISCHER & PORTER COMPANY INSTRUMENTATION AND CHLORINATION FP

The Importance of People

The future of U. S. water supplies rests largely with the American public. The knowledge of the hydraulic engineer, the skill of the operating mechanic, the craftsmanship of the manufacturer who makes water works supplies – these can function only as authorized to do so by the general public. Water works have become mostly public utilities. Water works improvements are therefore done with public funds, and it is the people who say yes or no.

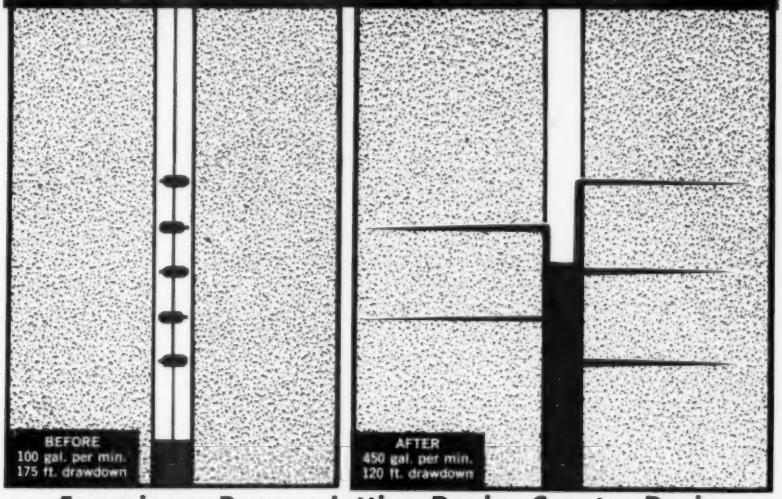
Perhaps the greatest handicap in development of water supplies for over three-quarters of a century is the public opinion that water is cheap, simply because in pioneer days well water and spring water were free. This popular misconception has kept water rates too low to finance improvements as needed. Result: A 30-year-period of delay and a $41 billion deficit in funds for water works and sewage works construction needed to meet today's requirements.

"Where there is no vision, the people perish," says an Old Testament Proverb. The first and the biggest job of water works men and city officials now is to inspire vision in the people of their community. Once they know the facts, the people will act for their own welfare.

This series is an attempt to put into words some appreciation of the water works men of the United States.

M&H VALVE AND FITTINGS COMPANY
ANNISTON, ALABAMA
SUBSIDIARY OF WALWORTH

Water Well Stimulators Increase Flow Up to 1000% At Nominal Cost!



Experience Proven Jetting Device Creates Drain Holes Deep into Aquifer in a Matter of Minutes!

Data obtained from actual experience indicates that Birdwell Water Well Stimulators will more than double the production of most existing industrial and municipal "rock" water wells — at a cost of only $440.00 to $1000.00.

Birdwell Water Well Stimulators are specially designed explosive jetting devices that clean the borehole wall and create large diameter radial drain holes extending several feet into the aquifer. Birdwell jetting devices are available for wells of any diameter.

More than 100 drain holes can be made with a single trip into the well, and the entire operation takes only a few hours. Birdwell Water Well Stimulators mean little or no clean out, less "down" time for your well, less cost to you.

If your present water supply is inadequate, consult a Birdwell sales engineer before drilling another well or attempting remedial work — then decide for yourself the most economical way to obtain more water.

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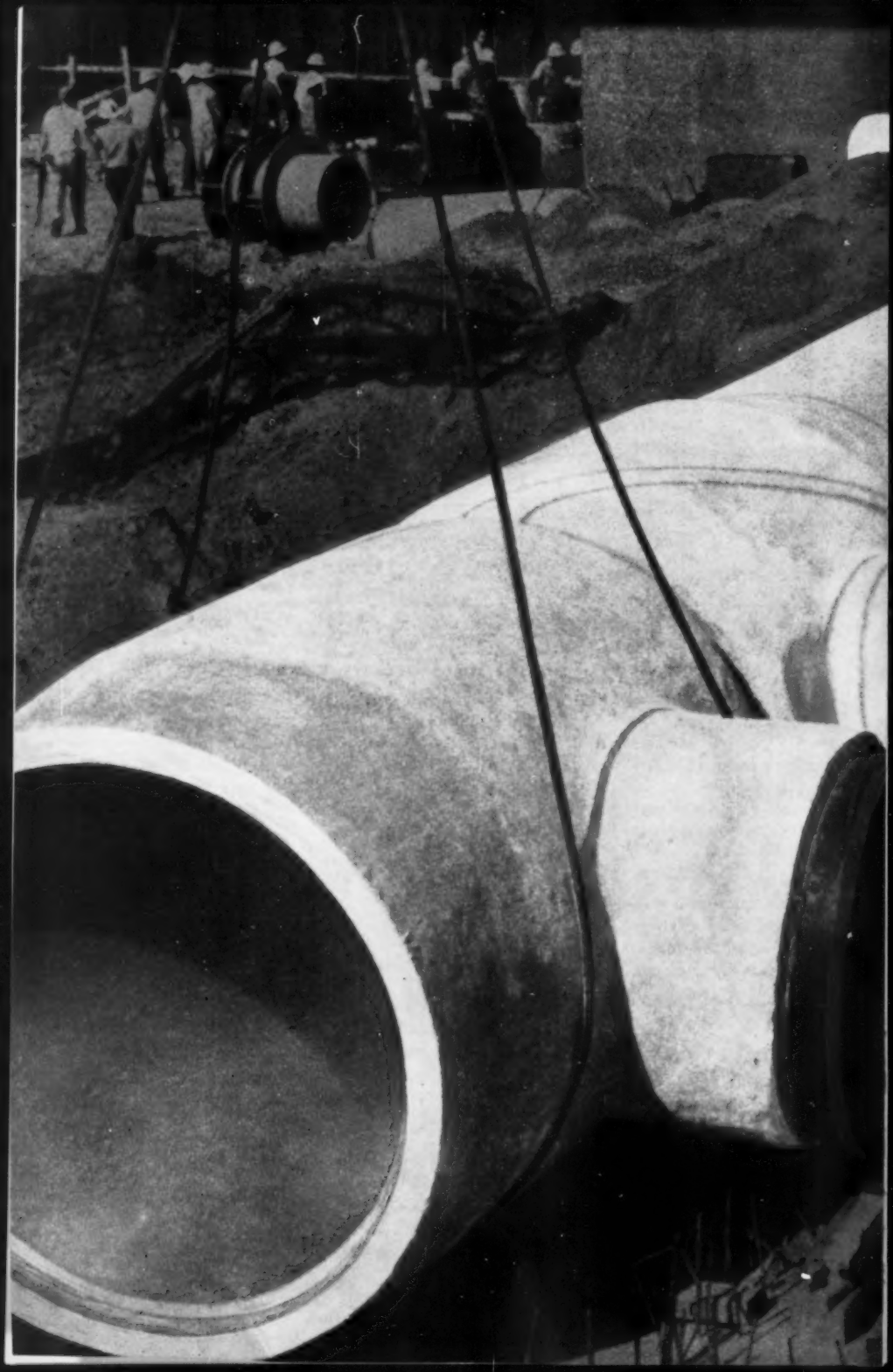

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In congested plant areas housing vital and costly equipment, major piping materials must, above all, be reliable. Conclusive evidence of concrete pressure pipe's reliability lies in its unexcelled record for durability, trouble-free service and exceptional safety.

Plant piping must also be adaptable. The tailor-made characteristics inherent in concrete pressure pipe design make it an ideal material to meet the complexities of accurate entry into structures, and of precise juncture with fittings within the limited confines of plant buildings.

Dependable, maintenance-free, and with sustained high carrying capacity, concrete pressure pipe assures reliable plant piping, whether for water or sewage treatment plants, for industrial supply lines, or for cooling or process water systems.

WATER FOR GENERATIONS TO COME

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A full-fledged line-operated pH Meter of remarkable accuracy and stability at the low price of

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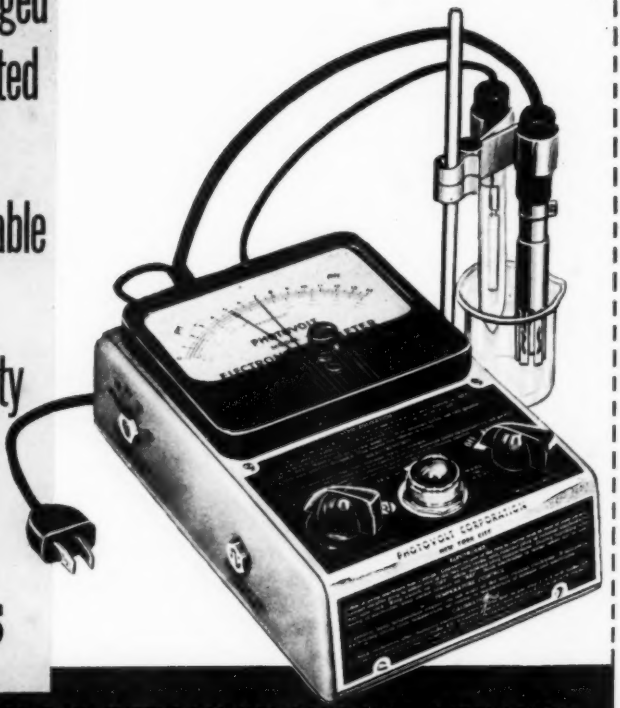

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Write for Bulletin #225, also for literature on other Line-Operated and Battery-Operated Photovolt pH Meters

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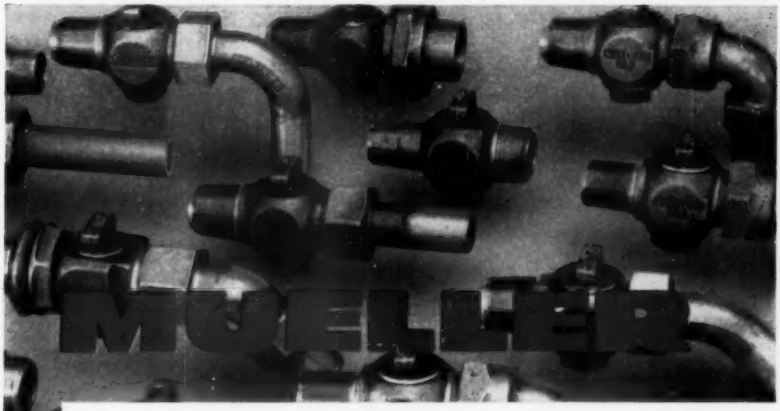

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Which type best fits your use? There are more than 50 different models of Mueller Corporation Stops regularly produced and stocked today. Each of these models has been specifically designed to fit the varying needs of your water distribution systems. Yet, each of these stops offers the same time-proven advantages—individually-lapped, ground key—designed, manufactured and individually* tested as a "quality-matched" companion to Mueller Tapping Machines and Tools.

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*EVERY MUELLER CORPORATION STOP IS FULLY TESTED IN BOTH THE OPEN AND CLOSED POSITION WITH AIR PRESSURE UNDER WATER. (THIS IS A MUCH MORE EXACTING TEST THAN A HYDROSTATIC TEST.)

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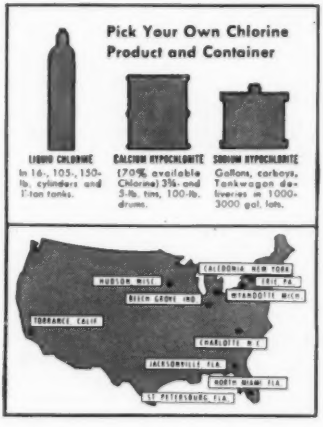
ONE convenient source for all your chlorine needs

Get chlorine products any way you want them, in any amount you need, from just *one* dependable source—Jones Chemicals.

It eliminates hop-scotch buying of liquid chlorine, calcium hypochlorite, or sodium hypochlorite, and enables you to plan your needs and deliveries . . . avoid excess storage. Eleven Jones plants, strategically located across the U.S., stand ready to deliver chlorine products *when you need them.*

Get chlorine in any amount—from 16-lb. cylinders to 1-ton tanks. Jones packages high-purity chlorine in less than carload lots. You pick the size and type of container you need.

Our trained technical staff will be glad to help you with your chlorine problems. Write for information and prices, or contact the Jones plant nearest you.



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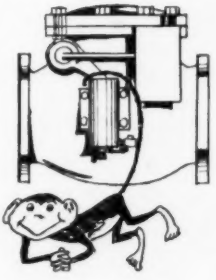
Don't monkey with hammer and shock in your water lines. Use a G-A Cushioned Swing Check Valve with the special cushion chamber that eases it through the last 5% of its stroke. Let the valve with the built-in "pillow" protect your equipment.

Write today for Bulletin W-1A.



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ME* can do!

During your next planning pow-wow on a forthcoming project, consider this challenge (ME* Can Do!) from a tribe of "Injun-eers" who make motors and generators their only business . . . and who have been successfully conducting this business on product merit for nearly 50 years.

Feathers in our bonnet include some of the world's most honored projects and our scalp belt includes a multitude of the leading names in industry, but the Chiefs at ME* are more interested now in what ME* can do . . . for you!

Wherever you are, whatever your requirements, there's an ME* Sales Engineer ready to visit your reservation, sit in at your council fire and discuss your requirements . . . help you with your planning . . . prove the superiority of Marathon Electric Motors and Generators.

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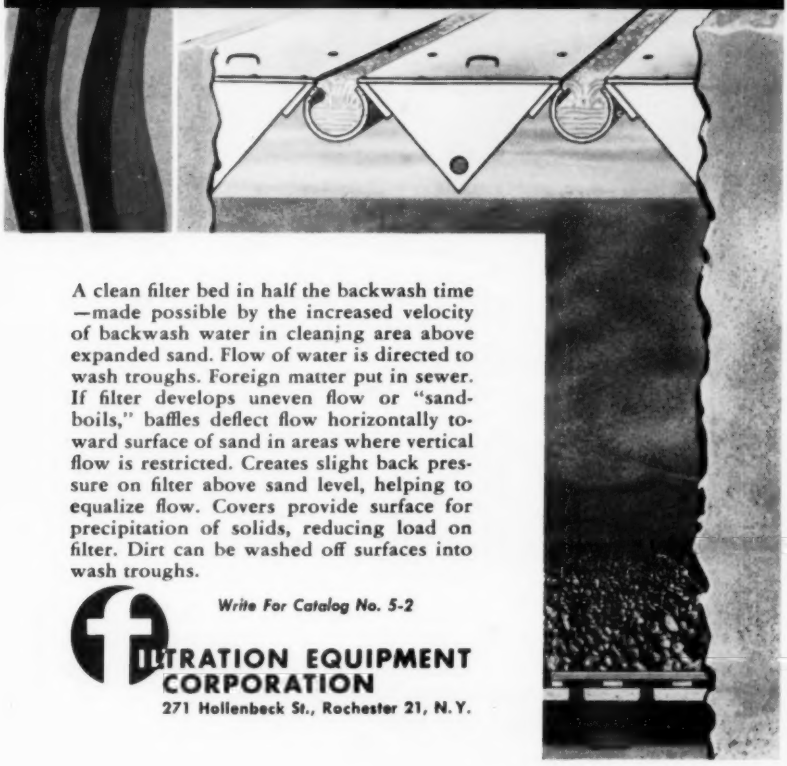
Cuts Backwash Cleaning Time in Half . . .

THE NEW feco LIGHTNING SURFACE WASH BAFFLES for RAPID SAND FILTERS



A clean filter bed in half the backwash time —made possible by the increased velocity of backwash water in cleaning area above expanded sand. Flow of water is directed to wash troughs. Foreign matter put in sewer. If filter develops uneven flow or "sand-boils," baffles deflect flow horizontally toward surface of sand in areas where vertical flow is restricted. Creates slight back pressure on filter above sand level, helping to equalize flow. Covers provide surface for precipitation of solids, reducing load on filter. Dirt can be washed off surfaces into wash troughs.

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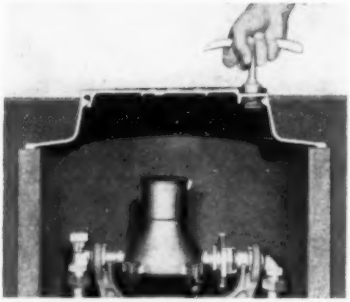

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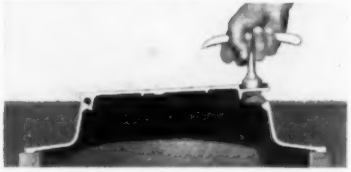

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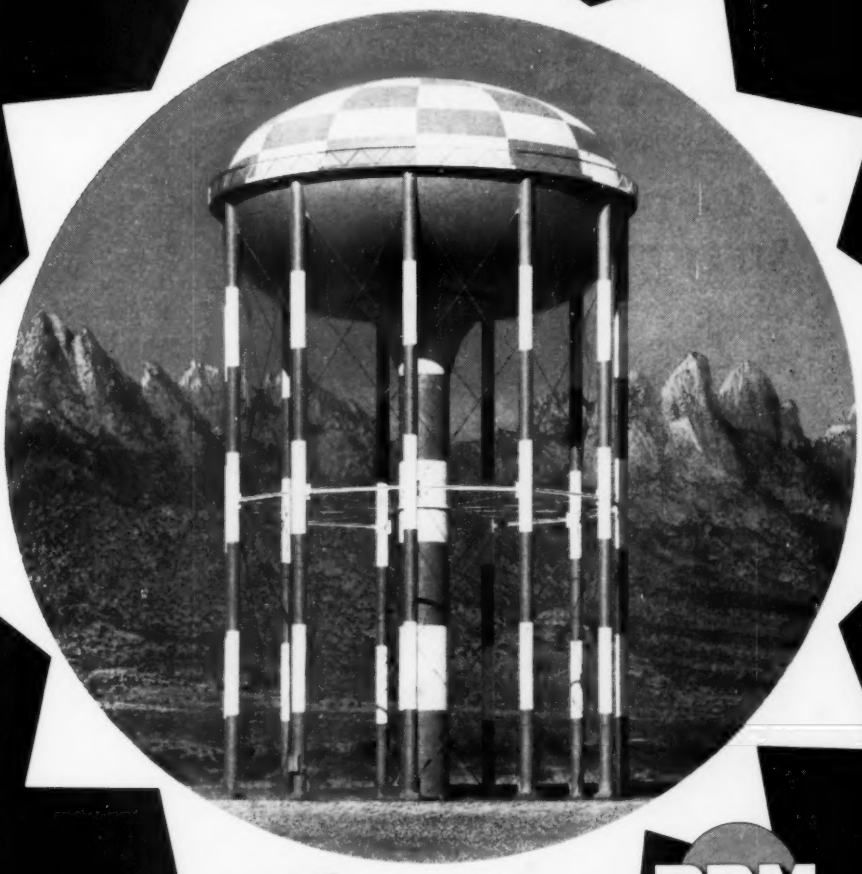

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Review of Desalinization Processes

Panel Discussion

A panel discussion presented on Oct. 21, 1959, at the joint meeting of the Alabama-Mississippi and Southwest sections, New Orleans, La.

Recent Developments—*Joseph J. Strobel*

A paper presented by Joseph J. Strobel, Chief, Processes Development Div., Office of Saline Water, US Dept. of the Interior, Washington, D.C.

THE problem of water supply is receiving increasing attention—and with good reason. The United States now needs about 300 bgd of water. If population and water use trends continue, then by 1980 the quantity of water needed will be 500–600 bgd. The Secretary of the Interior, in his address to the 1959 AWWA Annual Conference in San Francisco, said that adequate water supply in the United States could become the nation's primary domestic problem in a relatively few years.

One answer to the growing problem is to tap the practically inexhaustible supplies of the oceans and the large brackish water supplies of inland areas. The question is how to obtain fresh water from these sources at costs low enough for widespread use. The Department of the Interior, through the Office of Saline Water, is attempting to answer that question. A research and development program to find economical methods of producing fresh water from sea and brackish waters was initiated in 1952, when Congress enacted the Saline Water Act. In 1958, Congress authorized construction of demonstration plants to test some of the more advanced conversion processes. Construction and operation of demonstration plants will complement the existing research and development activities. Three plants are to be built for sea water conversion and two for brackish-water conversion.

Saline-water conversion has advanced to include a number of different processes. Major groups are: (1) distillation with the use of fuels; (2)

solar-heat distillation; (3) membrane processes; (4) separation by freezing; and (5) other chemical, electrical, or physical conversion methods. The first four will be discussed by this panel, and a brief review of the status of conversion processes development will be given here. With the highlighting of activities in areas of development, it is hoped that the relationship of the various processes will fall into perspective.

No one process will ever be completely practical for all saline-water conversion. Different processes are advantageous for either of the two major divisions of water to be treated—sea water and brackish water. In addition, other factors related to location, such as fuel costs, weather conditions, and waste disposal conditions, can determine which of several processes would be the most economical.

Distillation Processes

The distillation processes include several that are among the most advanced: multiple-effect distillation, with submerged-tube evaporators; multistage flash distillation; and tubular vapor compression distillation. A fourth, which has recently advanced to the point where it can be considered for large plants, is the long-tube, vertical, multiple-effect distillation process (LTV), using special scale control techniques. Other distillation processes under development include rotary vapor compression; tubular vapor compression, with forced circulation; single-stage flash, utilizing naturally occurring temperature differences; and, very recently, a vapor reheat multistage system and a multiple-effect process, using thin, wiped film with new fluted condensing surfaces.

The multiple-effect submerged-tube and vapor compression distillation processes have been used commercially for many years. More recently, the use of multistage flash is becoming more prevalent, particularly in large installations for sea water conversion which use several million gallons of water a day.

Because of their advanced developmental status and the possibilities of further improvement, the LTV process and the multistage flash process have been chosen for the first two sea water conversion demonstration plants, each of which has a capacity of approximately 1 mgd. The first sea water plant will be at Freeport, Tex.; the second, at San Diego.

Progress in the reduction of distillation costs has been made and will continue. In the late 1930's, it cost \$4–\$5 to produce 1,000 gal of fresh water from sea water by distillation. Since then, inflation has increased all dollar costs. Nevertheless, the cost of sea water conversion has been reduced and, in the most efficient, large sea water conversion plants, the cost is now about \$2 per 1,000 gal. It is anticipated that the first two sea water distillation demonstration plants will produce fresh water from the sea for about \$1 per 1,000 gal.

Solar Distillation

Solar distillation has the advantage of eliminating the cost of fuel, but the problems of research and development related to such distillation are difficult to solve. Because of the diffuse nature of solar energy, ways must be found to build equipment at very low cost, of high efficiency, and with low operation and maintenance costs, in order to produce converted water at prices competitive with those of water from other methods of distillation using fuels. In certain areas, however, particularly in

those of high solar intensity, solar distillation may, in the future, provide the best means for conversion. Small commercial solar distillation units are now in operation in several foreign countries.

There are some promising approaches toward solutions of solar distillation problems. More answers are being obtained from building and operating prototypes of solar stills and small pilot plants. One of the major activities of the Office of Saline Water is at a solar research station at Daytona Beach, Fla., where experimental stills are now in operation. A pamphlet describing the activity at Daytona has recently been published by the Department of the Interior.[1] The utilization of solar energy should become increasingly important in the future.

Membrane Processes

Several membrane processes are developing into economical means of converting saline water. The most important application is in the treatment of brackish water, but future developments in both membranes and equipment may make these processes useful for the conversion of sea water.

Electrodialysis processes are the only membrane conversion processes which, at this time, have advanced beyond the research or laboratory stages of development. Commercial units are now available and a number are in use. These processes have become sufficiently developed for one to have been selected for the first demonstration plant for the conversion of brackish water, which will have a capacity of about 250,000 gpd. Depending on the initial salt content of the water to be treated, it is anticipated that the cost of water from this plant will be in the range of 70–80 cents per 1,000 gal. Electrodialysis, particularly because it is a new process, is expected to undergo substantial improvement and cost reduction through additional research and development. Other membrane processes, such as reverse osmosis and osmionisis, may be developed for commercial use.

Freezing Processes

The development of freezing processes is very new. They have certain inherent advantages that should make them more than competitive with the better distillation processes. Two methods of saline-water conversion that are direct freezing processes include one in which water vapor itself serves as a refrigerant and one utilizing a secondary refrigerant such as butane. A 15,000-gpd pilot plant incorporating the first process is now operating. Several research and development groups working on direct freezing with secondary refrigerants are very optimistic about the possibilities of this method. Laboratory results have been very encouraging. Conclusions as to the economic feasibility of freezing processes must await the result of more extensive pilot plant operations.

Estimated conversion costs for freezing processes are in the range of $1 or less per 1,000 gal. The possible advantage of freezing processes in the conversion of brackish waters with a large content of calcium sulfate should be noted.

Other Processes

In regard to other processes, the one furthest advanced in the laboratory is that of solvent extraction. Additional development will provide the answers concerning the financial aspects of the process. Its most promising application would be for the treatment of brackish waters containing 5,000–

10,000 ppm of dissolved solids. A newer conversion process, now becoming of great interest, on which laboratory work has been carried out, involves the use of gas hydrates. The process utilizes a hydrocarbon gas, such as propane, to form hydrate crystals from which the desalted water can be recovered.

Conclusion

An overall view of the saline-water conversion field makes clear that there is a progressive program of research and development in many areas and that more such activity is needed. Conversion costs are being reduced. At the same time, costs of fresh water from natural sources are rising. Use of conversion is increasing. In a number of places throughout the world, as in the Persian Gulf area and Aruba in the Caribbean, many millions of gallons of fresh water for both industrial and domestic uses are being obtained from salt water every day. Continued efforts in basic research, in the development of processes, and in the operation of demonstration plants, and continued research on broad problems relating to scale, corrosion, and improved heat transfer, can result in better and lower-cost saline-water conversion. Thus, additional, enormous supplies of fresh water will become available at prices low enough to permit widespread use.

Reference

1. US DEPT. OF THE INTERIOR. Sea Water Conversion: Solar Research Station, Daytona Beach, Fla. US Govt. Printing Office, Washington, D.C. (1959).

Membrane Processes—*Ernest H. Sieveka*

A paper presented by Ernest H. Sieveka, Process Engr., Office of Saline Water, US Dept. of the Interior, Washington, D.C.

Processes utilizing membranes have, in recent years, received considerable attention with regard to saline-water conversion, both in experimental work and as pertains to actual commercial water production units. The most promising immediate applications appear to be for the conversion of brackish waters rather than sea water. The first commercial saline-water conversion unit utilizing membranes in the electrodialysis process was introduced in 1954. The interest in membrane processes for conversion of saline waters has grown steadily since then, and electrodialysis remains one of the more promising processes for the conversion of brackish waters.

Characteristics of Membranes

A membrane may be defined, from a conversion standpoint, as a sheetlike barrier that may function in one of two ways: It may be ion permeable—that is, it may pass ions and prevent the passage of water—as in electrodialysis, or it may be ion restraining—that is, it may prevent the passage of ions but permit the passage of water—hence an osmotic type of membrane. Processes based on these membranes include the electrodialysis, osmionic, and reverse-osmosis processes. Electrodialysis is the best known among the membrane methods, because it was the first to be used commercially. The osmionic process also utilizes the ion-permeable membrane; the reverse-osmosis process uses the osmotic or ion-restraining membrane.

The membrane processes differ from those of distillation and freezing in that no change of phase occurs. Also, in the membrane processes no tem-

perature change is required; hence, heat need not be added or removed from the water. Furthermore, electrodialysis and osmionisis remove the salts from the water; distillation and freezing remove the water from the salts. In the electrodialysis process and, similarly, in the osmionic process, the electrical energy that must be supplied is proportional to the salt removed. Thus, waters of low salinity require a proportionately smaller amount of electrical energy as compared with waters of higher salinity. For processes such as distillation and freezing, for example, the energy required is relatively independent of the amount of salts present. The reverse-osmosis process resembles distillation in that the water is removed rather than the salts. Reverse osmosis, however, resembles the other membrane processes in that there is no change of phase, no heat is supplied, and the osmotic pressures of less saline waters are correspondingly lower than those of more saline waters, such as sea water. Thus, the pressure required to effect water removal by reverse osmosis is correspondingly less for waters of lower salinity. It is these characteristics that make the membrane processes generally more favorable for conversion of brackish waters than for conversion of sea water.

Electrodialysis Membranes

For those concerned with water conversion for municipal or industrial purposes, electrodialysis is of most immediate interest. A brief review of the basis for the electrodialysis process seems desirable, for its principles are generally not familiar to those in the water treatment field. The membranes themselves are the most vital component in the unit and hence warrant some discussion before the mechanics of the process are reviewed.

The ion-permeable membranes used in electrodialysis are of two types: the so-called cation membranes, which transmit cations (Na^+, for example) but prevent passage of anions, and the anion membranes, which permit the passage of anions (Cl^-, for example) but prevent the passage of cations. These membranes owe their preferential permeability to the ion-exchange materials that are a part of their composition. Thus, they were originally referred to as ion-exchange membranes. When compared with ion exchange in conventional water treatment, the term "ion permeable" is more appropriate, because the membranes do not operate in a manner similar to ion exchangers in the usual sense as pertains to water treatment. It may be said that the membranes always operate in the fully regenerated state and never undergo a cycle of exchange and regeneration. They operate rather as a relay or transfer medium for the ions to which they are permeable.

Figure 1 illustrates how the chemical structure of membranes makes possible the preferential transfer of either positive or negative ions. As shown, the body of the membrane consists of an insoluble matrix to which are attached fixed charges. These charges are positive for the anion-permeable membrane and negative for the cation-permeable membrane. Associated with each fixed charge is a mobile charge of opposite sign. Although the membranes pass only very limited amounts of water, even under a considerable hydraulic pressure gradient, they do contain a large quantity of water (30–40 per cent). Hence, mobile ions moving within the membrane matrix may be considered as traveling in a water solution within the membranes, much as they do in a water solution outside the membranes.

Chemically, the insoluble matrix, with regard to the cation-permeable membrane, may be a polymeric substance such as a phenol-aldehyde resin, a polystyrene-divinylbenzene copolymer, and the like. The active functional group, linked to the polymeric matrix to provide the fixed negative charge, may include the sulfonic ($-SO_3H$), carboxyl ($-COOH$), and similar acidic groups. The positive ions within the saline water—for example, Na^+, Ca^{++}, and Mg^{++}—become the mobile ions within the matrix, because they can exchange with the mobile positive charges associated with the functional acidic group. In contrast to this reaction, ions in the water solution having charges the same as those on the fixed charge of the matrix will be prevented from entering the membranes, because they cannot undergo the ion-exchange reaction with the mobile ions. This effect may be explained also by the well known rule that like charges repel; hence, ions having charges the same as the fixed charge on the matrix are prevented from entering the membrane.

As regards the anion-permeable membrane, the insoluble matrix may be of typical polymers, such as the urea-formaldehyde, melamine-formaldehyde resins and the like. The active functional groups linked to the polymeric matrix to provide the fixed positive charge may be the quaternary ammonium, amino, guanidyl, and similar basic groups—that is, $-NH_2$, $-NHR$,* $-NR_2$, and $-NR_3OH$. The negatively charged ions within the saline water—such anions as Cl^-, SO_4^{--}, and CO_3^{--}, for example—become the mobile ions within the matrix, because they can exchange with the mobile negative charge associated with the functional group. Because of the ease with which the charged ions can be exchanged within the matrix, an electrical potential, when applied across the solution, can readily move ions of the appropriate charge through the membranes.

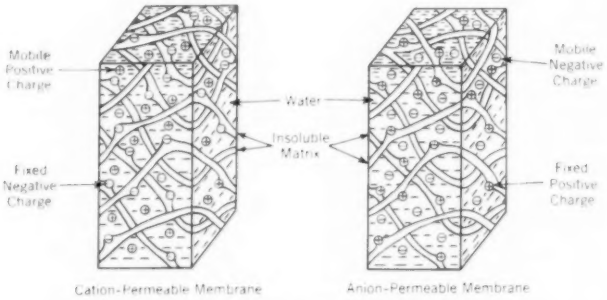

Fig. 1. Chemical Structure of Membranes

The mobile positive charge pertains to such cations as Na^+, Ca^{++}, Mg^{++}, K^+, and H^+; the fixed negative charge, to such active groups as $-SO_3H$, $-COOH$, and $-OH$. The mobile negative charge pertains to such anions as Cl^-, SO_4^{--}, CO_3^{--}, and NO_3^-; the fixed positive charge, to such active groups as $-NH_2$, $-NHR$, $-NR_2$, and $-NR_3OH$. The thickness of the membranes is 0.4–1 mm (0.010–0.040 in.).

* "R" represents polymers to which functional groups are attached.

From the standpoint of physical composition, the membranes may be divided into two categories: heterogenous and homogenous. The former is composed of ion-exchange materials held together in sheet form by an appropriate binder. The homogenous membranes, in contrast, are of uniform composition, with the ion-exchange groupings an integral part of the sheet material. Most of the membranes used in the United States today are of the homogenous type. Another type of membrane, varying somewhat from the above categories, is formed by impregnating porous reactive substances, such as parchmentized paper or cellophane, with solutions providing the ion-exchange materials.

With regard to their strength, membranes are further classified into those that have an inert backing to provide strength and those that have no backing, but which rely on the actual membrane material to provide their necessary strength. To be satisfactory, from a technical standpoint, for use in electrodialysis, a membrane must meet various requirements. It should have a high degree of permeability—that is, it should pass only very few of the ions for which it is not intended to be permeable. It should have a very low electrical resistance. It should be resistant to chemical and bacterial attack, particularly to pH changes, free chlorine, or other conditions that may be encountered in water treatment. Moderate temperature changes should not affect its operation. It should have a reasonable life, be durable, and not subject to dimensional changes—that is, it should not develop cracks, wrinkles, shrinkage, or expansions that would prevent its effective use in an electrodialysis cell. Fortunately, a number of satisfactory membranes are now available. Electrodialysis would not have been possible without the membranes developed in recent years.

Figure 2 shows what happens in the electrodialysis process. In the upper part of the figure is an electrodialysis unit with electrodes at either end, but with no current flowing. The vertical lines labeled *A* or *C* represent the membranes: *A*, the anion-permeable membrane; *C*, the cation-permeable membrane. The illustration shows an end view of the units and only the edges of the membranes. The membranes may be thought of as flat plastic sheets with a space between them for water flow. In the upper diagram, the unit is filled with saline water, but the current has not yet been turned on. Hence, there is no movement of the ions, and they will be equally distributed in the compartments. When the current is turned on, the anions (Cl^-) start moving toward the anode, and are passed readily by the anion membrane, but find themselves restrained by the cation membrane and unable to travel further. The cations (Na^+) start moving toward the cathode and pass readily through the cation membrane, but find themselves stopped by the anion membrane. Hence, a condition as seen in the bottom portion of Fig. 2 results, with both anions and cations concentrated in compartments, with the adjoining compartments free of salt ions. The flow from the two series of compartments can be channeled into two streams, one fresh water and one very salty.

The thickness of the membranes may vary from a millimeter (0.040 in.) to as little as a few tenths of a millimeter. The space between the membranes, which carries the fluid stream, will generally be approximately a millimeter thick.

Electrodialysis Unit

Figure 3 shows the basic electrodialysis unit, commonly known as a "stack." The unit shown is a stack in the demineralizer * that was field tested under contract with the Office of hydraulic spacers between the membranes to provide the necessary flow paths for the water between the membranes or within the cells. Two membranes, one anion and one cation, with the hydraulic spacer in between, form a single cell. All gasketing in a stack

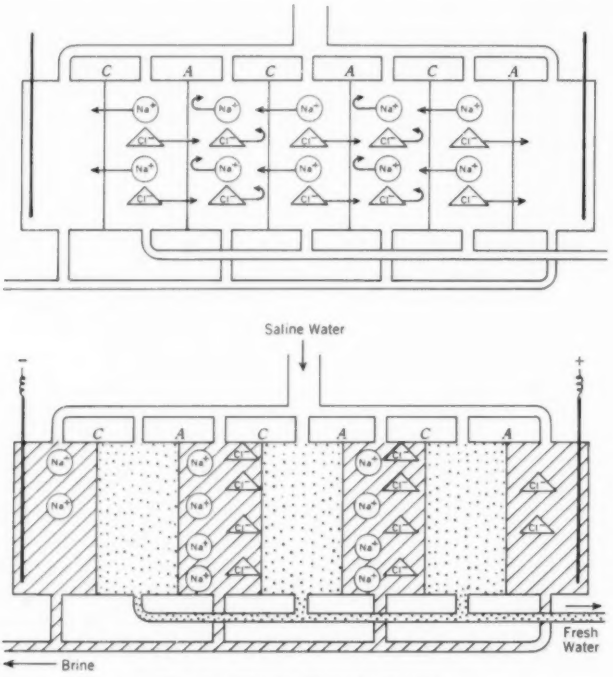

Fig. 2. Electrodialysis Process

The top unit, with the current turned off, is filled with saline water. When the current is turned on, anions and cations become concentrated in alternate compartments, and the water in adjoining compartments becomes free of salt ions. The vertical lines labeled A *or* C *represent membranes:* A, *the anion-permeable membrane;* C, *the cation-permeable membrane.*

Saline Water. In this stack, the membranes are horizontal. There are 150 cell pairs or a total of 300 membranes (150 anion and 150 cation), with 300 such as the one shown is provided by the membranes and spacers themselves. All flow channels are manifolded within the stack itself by the appropriate cutting of holes within the membranes and spacers, so that when they are assem-

* Manufactured by Ionics, Inc., Cambridge, Mass.

bled, a channel is provided through the unit. There are separate flow paths for the electrode stream, the product stream, and the waste stream. Electrodes are located at either end of the stack. With this arrangement, the direct current travels between the top and bottom ends of the stack, and water flows horizontally across the path of the current, from left to right.

Research and Development

The Office of Saline Water, early in the saline-water conversion program, sponsored a development contract that resulted in the construction of a 25,000-gpd pilot plant unit, field tested in Arizona and South Dakota during 1955. The interior of the trailer-mounted unit is shown in Fig. 4. The unit consisted of four stacks, which, when operated in series, could reduce the mineral content of water from 4,000 ppm to 500 ppm, at the rate of 1,000 gph, or approximately 20 gpm. The current required was about 7 kwhr per 1,000 ppm of salt removed from 1,000 gal of water, or about 25 kwhr to reduce the 4,000-ppm mineral content to 300 ppm. Results of the field tests have been detailed in a report of the Office of Saline Water.[1] An analysis of the well water treated in Arizona and the product water produced is given in Table 1. The analysis indicates that all the major components were readily removed, with the exception of silica and boron, which were removed very little or not at all.

Although the field unit was for experimental purposes, the stacks were the regular commercial type used at that time. It should be noted, in all fairness to the progress that has been made in the design and engineering of similar units, that at the present time the hydraulic capacity for the same size

TABLE 1

Analysis of Arizona Well Water

Mineral	Concentration in Untreated Water *ppm*	Concentration in Demineralized Water *ppm*
Silica	33	33
Iron	0.15	0.04
Calcium	445	9.9
Magnesium	181	4.8
Sodium	606	55
Potassium	8.5	0.6
Boron	1.0	1.2
Bicarbonate	360	62
Sulfate	1,040	51
Chloride	1,290	44
Fluoride	0.6	0.2
Nitrate	45	0.2
Total solids	3,830	229
Hardness (as $CaCo_3$)	1,850	44

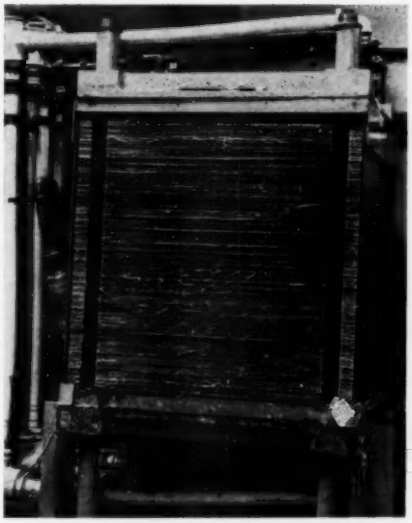

Fig. 3. Basic Electrodialysis Unit

In this stack, there are 300 membranes—half of them anion membranes, half cation—and 300 hydraulic spacers in between.

stack is more than twice as great, and the percentage of demineralization per stage has also been increased.

Field testing of the unit indicated to what extent the chemical characteristics of different brackish waters influence the operation of an electrodialysis conversion unit. By comparison with sea water, which is generally uniform in composition, there are almost as many types of brackish water as there are sources for it. Each water may have a somewhat different influence on the scaling, fouling, and brine waste flows that may be needed, or on the treatment required prior to conversion. To a degree, this will be true regardless of the process involved, for nearly all conversion processes encounter difficulty with scaling. In electrodialysis, for example, it has been found that the iron in the feedwater must be reduced to 0.3 ppm prior to entering the conversion unit. Therefore, waters having no iron do not need to be pretreated for its removal. Also, it has been found that to avoid precipitation of calcium carbonate or magnesium hydroxide in the electrodialysis units, the brine stream must be adjusted in pH and

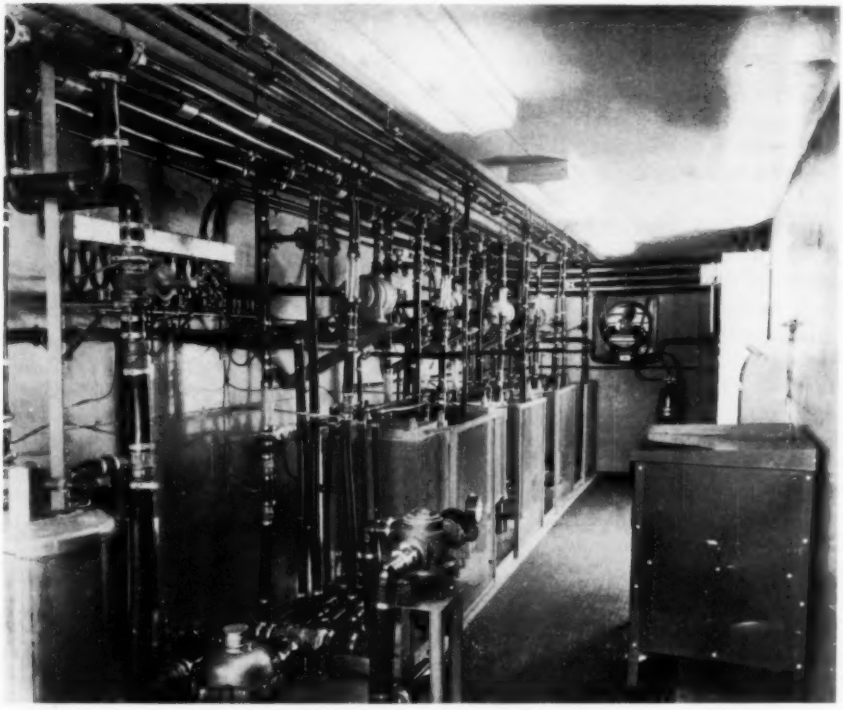

Fig. 4. Interior of Demineralization Pilot Plant

The trailer-mounted unit, field tested in Arizona and South Dakota during 1955, carries four stacks, shown standing along the left wall.

alkalinity to a nonscaling condition, as indicated by the Langelier saturation index. Furthermore, as is true also in other methods such as distillation, the minimum waste flow needed in an electrodialysis unit to prevent calcium sulfate precipitation is dependent on the calcium and sulfate concentration in the feedwater. Water containing primarily sodium chloride or similar salts will require only a limited amount of waste flow as compared to water containing large amounts of calcium sulfate.

Since the completion of the field test work, the Office of Saline Water has sponsored a program of electrodialysis studies at the Bureau of Reclamation in Denver. In conjunction with the Denver work, research has also been sponsored in electrodialysis membranes at the Polytechnic Institute of Brooklyn in New York. The current work at Brooklyn Polytechnic is directed toward the preparation of a manual of laboratory testing procedures for membranes. Up to this time, there has not been any standard set of laboratory testing methods such as the ASTM methods used for other purposes. A manual of laboratory test procedures should make possible a more uniform comparison and evaluation of membranes by all workers in the field.

The studies at Denver have been primarily of membrane life and durability, evaluation of new membranes, and evaluation of new cell designs. The studies of membrane life have indicated that a life of 3 years, which had been estimated for the membranes used in the field tests, was fully justifiable.

A number of new membranes and cell designs have been developed by various manufacturers in the last few years. Only limited information is available on these materials. It is the purpose of the work at Denver to evaluate the performance of these new membranes and cell prototypes and to keep abreast of progress in the field, so that the program may determine what areas need improvement and where Office of Saline Water funds

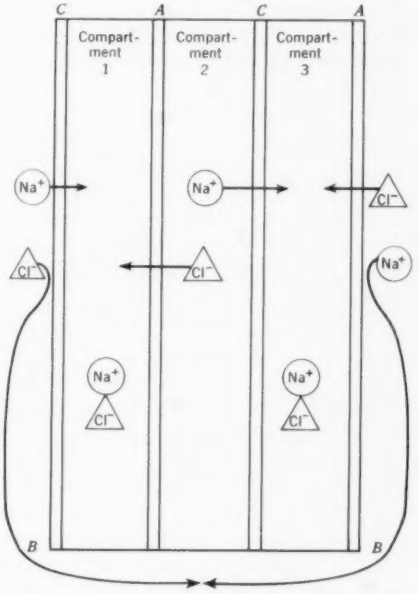

Fig. 5. Osmionic Demineralization Unit

Key: C, cation-permeable membrane; A, anion-permeable membrane; and B, continuous brine path.

can best be spent to improve the process. In addition, the work at Denver supports the demonstration plant program. The Bureau of Reclamation has been chosen to represent the Office of Saline Water in the contract work related to the construction of a 250,000-gpd electrodialysis plant, which is to be the first brackish-water plant to be

constructed under Public Law 85-883.

The demonstration plant should provide much valuable information both for the prospective user of the electrodialysis process and for the research and development engineer who is attempting to improve the process. The report on the field testing of the demineralizer provided much information to those interested in electrodialysis. It is also expected that the report on the demonstration plant a few years hence will provide an even greater amount of valuable information to those interested in this process.

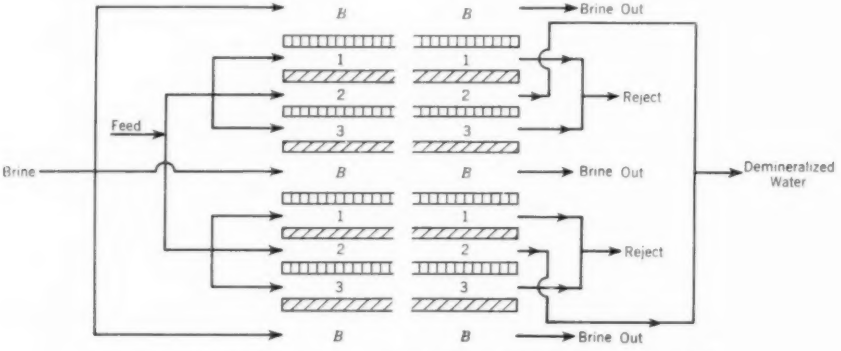

Fig. 6. Multiple Arrangement of Three-Compartment Assembly

The diagram shows two repeating single-stage membrane arrangements and fluid streams. B represents the path of brine. Numbers 1–3 designate the three compartments shown in Fig. 5.

Commercial Installations

Commercial installations of electrodialysis equipment are providing information on the cost of the process and its operating characteristics. Plants with capacities as large as 86,000 gpd are in operation, with the largest plant at Bahrein, on the Persian Gulf. A 3,000,000-gpd plant is under construction in South Africa. Recently, Coalinga, a small community in California, became the first town in the United States to obtain its drinking water supply from converted brackish well water. By use of an electrodialysis plant (28,000 gpd), the cost of its water was cut to about $1.50 per 1,000 gal, as compared to about $7.00 per 1,000 gal it had cost to haul in drinking water. The site for the 250,000-gpd electrodialysis demonstration plant to be built by the Office of Saline Water has not yet been selected, but the plant will be located in either the Northern Great Plains or the arid area of the Southwest. Depending on the initial salt content of the water to be treated, it is anticipated that the cost of the water from this plant will be in the range of 60–80 cents per 1,000 gal. Inasmuch as electrodialysis is, comparatively speaking, in its earlier stages of development, continued research can be expected to lead to substantial improvements and cost reductions.

Osmionic Process

The osmionic process, developed by George Murphy of the University of Oklahoma, is now undergoing more extensive laboratory development at the Southern Research Institute at Birmingham. The name "osmionisis" was given the process by Murphy because of the osmotic and ionic forces involved in its operation. In principal, it is similar to the electrodialysis process and uses the same type of membranes. In osmionisis, however, no electrical current is employed; instead, the potential provided by a strong brine solution, much more concentrated than the water being converted, removes the salt ions from the water, using the same membranes as in conventional electrodialysis. The potential being utilized is that which exists between salt solutions of different concentrations and is commonly referred to in physical chemistry as a concentration potential.

One advantage of osmionisis is that no electrical equipment is required, thus greatly simplifying the mechanical features of the process. A further advantage is that the energy required may be provided through any available salt brine, which may in turn be obtained from salt deposits, brine wells, or sea water that has been concentrated by solar evaporation. Osmionisis, therefore, provides an indirect means of utilizing solar energy to supply the necessary electrical energy in a membrane process.

The possible future potentials of the osmionic process have not yet been fully determined. Only laboratory units have been built to date, but consideration has been given to a larger prototype unit. The economics of the process is influenced considerably by the membrane areas required. At present, osmionisis appears to be best adapted to brackish-water conversion. The process should offer promise for areas that can provide brackish waters and brines, but where electrical energy sources are limited or unavailable for other processes. The theory on which the process is based and the initial work by Murphy are described in a report of the Office of Saline Water.[2]

In its simplest form, the osmionic cell consists of four membranes, two anion- and two cation-selective membranes, making up three compartments (Fig. 5). In actual operation, each of the three compartments initially contains the saline water to be demineralized, and the entire assembly, consisting of the three membrane compartments, is immersed in and surrounded by a brine solution. Demineralization is achieved in the following manner: The cations (Na^+) pass through the cation-permeable membrane (C), and the anions (Cl^-) pass through the anion-permeable membrane (A). This movement of ions is electrostatically coupled with the simultaneous removal of negative ions and positive ions from the water in Compartment 2, so that this water becomes demineralized or fresh water. In maintaining electrical neutrality, it is necessary that there be a continuous brine path (B) around the assembly, so that Na^+ ions can migrate to the left and Cl^- to the right, around the assembly. Compartments 1 and 3 become enriched with salts and hence more saline than originally. The brine actually becomes a little less concentrated because of the migration of ions into these two compartments. Therefore, the brine that supplies the power must be kept up to strength. Either an additional supply of brine must be available or the brine already

in use must be reconcentrated by such treatment as solar evaporation.

The three-compartment assembly may be arranged in a multiple series. The flow of the fluid stream within such an arrangement is shown in Fig. 6. It is desirable to provide the shortest possible path of travel, between opposite ends of the series of compartments, for the positive and negative ions in the brine solution. Hence, it is desirable to arrange the series of compartments in a loop or head-to-tail arrangement (Fig. 7), so that a closed path for ion travel is provided.

In a typical membrane pack used in a prototype unit at the Southern Research Institute, the membranes are 8×32 in., providing an active membrane area of 1.78 sq ft for each of the four membranes. The average distance between membranes is 0.028 in. One of the laboratory units consisted of twenty double-effect cells (120 membranes), with dimensions as described above. The cells were assembled in a loop in a brine solution (Fig. 7). This unit had a capacity of about 1 gph when demineralizing a water from 3,500 ppm to 500 ppm. Work is continuing at the Southern Research Institute to determine both the membrane and operating characteristics of units having twenty or more cells that are used to convert brackish water to fresh water.

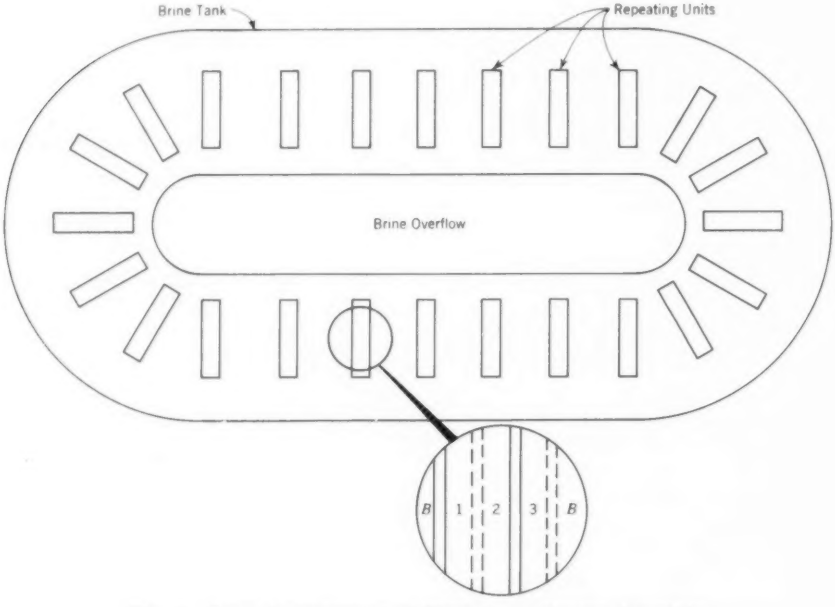

Fig. 7. Loop Arrangement of Three-Compartment Assembly

Each repeating unit is made up of two cation-permeable and two anion-permeable membranes, as shown in the enlarged portion of the diagram. B represents the path of brine. Numbers 1–3 designate the three compartments shown in Fig. 5.

Reverse Osmosis

Another membrane process that has been investigated extensively in the laboratory is the osmotic or reverse-osmosis method. The process depends on osmotic membranes—that is, membranes permeable to solvent but not to solute. Such membranes have long been known for some solutions—sugar in water or rubber in toluene—but practical membranes for solutions of salt in water have not been developed. The function of an osmotic membrane is, however, well known. If a solution is placed on one side of the membrane, and pure water on the other, water will diffuse through the membrane from the pure-water side to the salt-water side. This flow can be prevented by exerting a certain pressure, called the osmotic pressure, on the salt water. If a pressure higher than the osmotic pressure is exerted on the salt water, the flow will be reversed, and pure water will be moved through the membrane from the salt solution; hence the term "reverse osmosis." For sea water, the osmotic pressure is about 350 psi; it is lower for less saline waters.

Work on the reverse-osmosis process was initiated at the University of Florida. The results of the Florida work have been published by the Office of Saline Water.[8] It was demonstrated that conversion of sea or brackish water by this method is technically feasible, and a small laboratory unit capable of producing 2–8 gpd of converted water was constructed and tested. It was learned, however, that flow rates and durability of available membranes must be improved before a practical unit can be developed. The major part of the study was therefore directed toward determining the theoretical basis for the salt-rejecting properties of membranes, as a guide to better membrane selection, and toward testing various commercial plastic films. The plastic films tested included polyvinyl acetate, polyvinyl alcohol, rubber hydrochloride, nylon, polyethylene, and others. Of these, only cellulose acetate showed any notable salt-rejecting effect, reducing the salt content of water forced through it by about 95 per cent. An improved cellulose acetate film was produced which reduced the salt content by about 99 per cent. At 600 psi, the flow rate through the film was 0.11 ml/sq cm/hr—that is, 5.84 gpd from each square yard of membrane.

This film failed after 74 ml/sq cm (159 gal/sq yd) of water was treated. Its thickness was only about 6 μ, but when supported on a porous porcelain backing, it withstood the high pressure used. Obviously, both the flow rate and the life of the film were unsatisfactory for a practical water-producing unit.

Although suitable membranes are not yet available, certain favorable characteristics of the method make additional research on this process seem desirable. The process is basically simple in principle, and the total energy required should be low. The energy required can be readily calculated on the basis of reasonable assumptions regarding the operating conditions. A substantial part of the power required for producing the high pressures can be recovered through a turbine. Efficiencies of 75 per cent for pumps and 80 per cent for turbines are conservative estimates for large units. If the pressure used is 600 psi, and 25 per cent of the water passes through the membrane before the remainder is rejected, the energy required will be 12.8 kwhr per 1,000 gal of fresh water produced. The possibility of such low energy requirements is one of the features that

encourages further research to obtain suitable membranes for the process.

Recently, the Office of Saline Water initiated further research on osmotic membranes under a contract with Radiations Applications Inc. of New York. These studies will emphasize particularly the possibility of using radiation grafting techniques to develop membranes having more suitable characteristics. In addition to these studies, the University of California, under its own programs, is conducting research in the use of the reverse-osmosis principle.

Acknowledgment

Although development work sponsored by government funds has done much to improve the membrane processes, credit must be given to the industrial firms and private research organizations that have contributed their own funds and effort to this activity, particularly in the field of electrodialysis. The efforts of all those who have contributed to the developments that have made available the membranes and the commercial equipment used today are acknowledged.

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Freezing Processes—*Dewey J. Sandell Jr.*

A paper presented by Dewey J. Sandell Jr., Director of Research, Carrier Corp., Syracuse, N.Y.

Freezing processes for the separation of one component from a multicomponent chemical solution have been used for some time. Recent engineeering developments, however, indicate that these processes can be applied economically to separate a potable water from a salt solution.

Freezing processes may be classified as physical processes that separate water from saline solution. At first, this operation seems to be impractical because saline waters are approximately 96.5 per cent water and 3.5 per cent salt. Therefore, why not simply take the small salt portions out and leave the large volume of water? The answer is obvious. Technically, the operation can be done either way, but the main problem is to do it economically. This is the major reason that one hears today about the development of such processes as distillation, freezing, and membrane. A chemical solution of sodium chloride and water at 70°F requires, thermodynamically, a minimum isothermal work of 2.6 kwhr to separate 1,000 gal of fresh water from a 35,000-ppm saline solution. This assumes chemical reversibility of process and is independent of how the process is carried out. At 3.5 cents per kilowatt-hour, representative of electrical energy costs, this minimum theoretical work would amount to about 9 cents per 1,000 gal of water. It is well known that actual processes will be several times this theoretical cost.

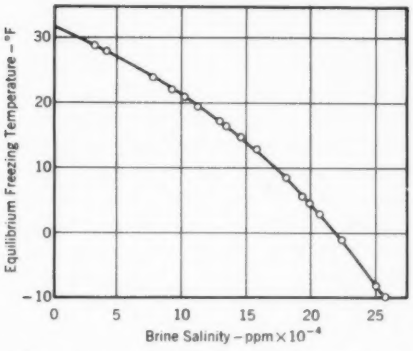

Fig. 8. Equilibrium Freezing Curve for Sea Water

At 28.5°F, water begins to crystallize from a 3.5 per cent brine solution.

Advantages of Process

In the freezing process, advantage is taken of the fact that, depending on salt concentration, when the temperature of a salt solution is lowered sufficiently, a separation of the components of the solution can be obtained. At 28.5°F, water begins to crystallize from a 3.5 per cent brine solution (Fig. 8). The crystals are pure water in solid form and, when separated from the brine and melted, become the freshwater product. One of the possible advantages of the freezing process is that approximately 150 Btu of heat per pound of solution must be removed to form a pound of pure water-ice. This compares to 1,000 Btu of heat per pound of solution that must be added to evaporate a pound of water from a saline solution. A part of this 1:7 energy ratio advantage is lost, however, in the irreversible (heat transfer fluid pumping) portions of the process. Thus, the energy ratio is not an indication of the actual cost ratio of obtaining fresh water utilizing the freezing process instead of the distillation process. Figure 9 shows the minimum energy requirements, in kilowatt-hours per 1,000 gal of fresh water, dependent on the extraction ratio—that is, at 50 per cent water removal the minimum is about 4 kwhr; and at 100 per cent, 12 kwhr, based on actual chemical activity coefficients.

Types of Processes

Indirect freezing. Freezing processes can be divided into two major categories—indirect and direct. In an indirect freezing process the salt water comes in contact with a heat exchanger that has cold refrigerant fluid flowing inside. The salt solution surrounding this heat exchanger is cooled, and ice is formed on the exterior surfaces. This is similar to the household refrigerator process of freezing ice cubes. The ice formed on the indirect freezing coil must be removed by a scraper or other mechanical device and subjected to a separation process to remove the brine that clings to the ice surfaces.

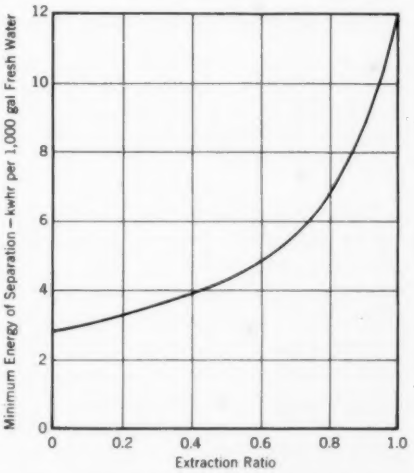

Fig. 9. Minimum Energy of Separation

The data are for a 3.5 per cent sodium chloride solution at 77°F.[1]

Because of the heat exchanger surfaces, secondary refrigerant cycle, and other mechanical equipment required, the indirect freezing process is not economical for saline-water conversion. Several system designs that utilize the indirect freezing method have been evaluated at Carrier Corp., Syracuse, N.Y., during the past 10 years. It has been concluded that the direct freezing process is more advantageous.

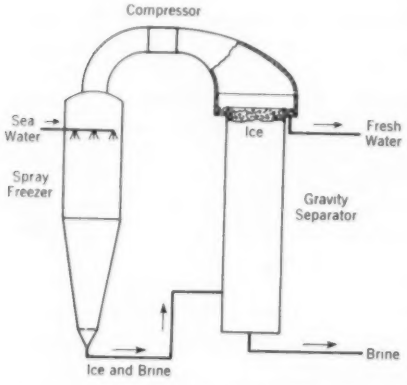

Fig. 10. Direct Freeze Separation Process

The process is a low-temperature (vacuum) distillation. A portion of the water of the saline solution vaporizes, removing heat and forming water vapor and ice crystals in the brine mixture.

Direct freeze separation. In a direct freeze separation process (Fig. 10), precooled sea water is sprayed or otherwise distributed into an evacuated chamber. The pressure of the chamber is approximately 3.4 mm of mercury. Under these conditions, a portion of the water of the saline solution vaporizes, removing heat and forming water vapor and ice crystals in the brine mixture. Thus, the freezing is obtained by direct evaporation of water into vapor, and no indirect refrigeration heat-transfer surface is required. Actually, the direct freezing process is similar to distillation; in fact, the process is a low-temperature distillation. The water vapor represents only about one-seventh the product water to be recovered, but at this temperature the vapor volumes are tremendous: 340,000 cfm for a 100,000-gpd capacity, which converts 50 per cent of the sea water into fresh water-ice. It is essential to recover the water vapor sprayed into the evacuated chamber; therefore, this water must be condensed and recovered as a fresh supply. The ice crystals formed during the direct freezing process are part of the brine mixture. The percentage of ice depends on the temperature and pressure conditions in the freezer. In the Carrier process, 50 per cent of the water from the incoming 3.5 per cent salt water solution is recovered. The solution pumped to waste or back into the sea is about 7 per cent brine. The percentage of water product is determined by costs of pumps, heat transfer surfaces, and energy requirements (electrical or steam). At about 50 per cent conversion, the costs are minimum.

The ice-brine mixture is pumped into a separation device to extract the brine from the ice crystals. The device may be a centrifuge, pressure extruder, or separation column. In the separation column, the ice floats or is forced by hydraulic-piston action to the top. The separated, heavier brine (7 per cent) flows to the bottom, owing to differences in specific gravity, and is discharged. The wash water added at the top of the column flows countercurrent to the rising ice crystals, washing the brine from the extended surfaces of the ice. The 7 per cent brine, which is at a temperature of 25.5°F, is used to precool the incoming sea

water. The water vapor from the freezer can be compressed to a pressure equivalent to the equilibrium pressure of water vapor at 32°F in a centrifugal or axial compressor. The vapor then condenses on the surface of the ice at the top of the column. This condensed vapor melts the ice, and the water formed becomes the fresh-water supply.

An alternative method of handling the water vapor is shown in Fig. 11.

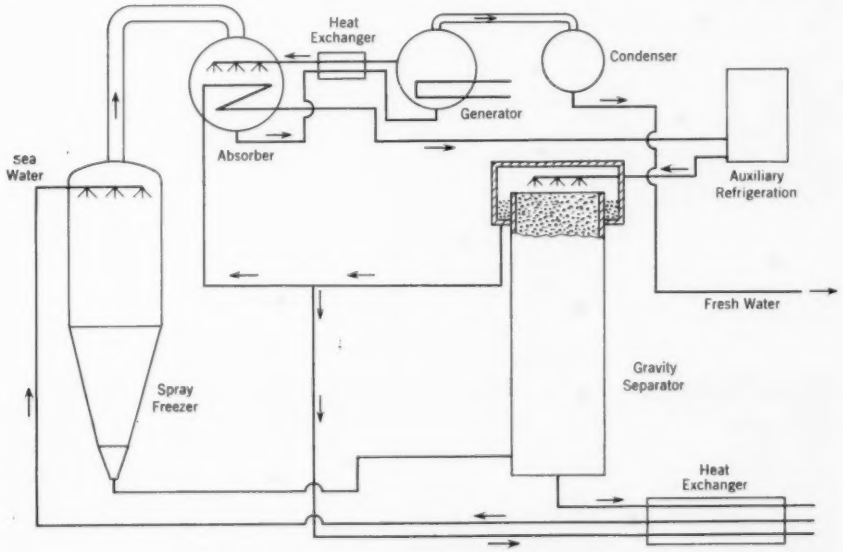

Fig. 11. Alternative Direct Freeze Separation

The process is the same as the one shown in Fig. 10, except that the water vapor is absorbed by a chemical absorption cycle.

The water vapor from the freezer is absorbed by a chemical absorption cycle. The absorbent soaks up the water vapor in the absorber and becomes dilute. This dilute solution is pumped to a generator, where it is heated while passing over steam coils. The water vaporizes and is condensed into fresh water. The concentrated absorbent is pumped through a heat exchanger back to the absorber to repeat the cycle. The condensed water vapor can be used for wash water in the column or used for a fresh-water supply.

Research and development on this method of converting saline water to fresh water (a solution of 35,000 ppm or less salts converted to a product of 500 ppm or less) have been carried out in Carrier Corp. laboratories during the past 5 years. Initially, the evaluation of the freezer and column operation was done on small, glass laboratory models. These tests were followed by extrapolation of equipment sizes to a 300-gpd capacity. The 300-gpd plant worked well, and the operating results provided the information needed for extrapolation of the design to a larger system.

The design of a 15,000-gpd pilot plant was completed in November 1958, and the construction and erection of the facility began in December and was completed in September 1959 (Fig. 12). The plant was dedicated by representatives of the Office of Saline Water on Oct. 14, 1959, at Syracuse, N.Y., when it was placed on stream to begin making ice from synthetic sea water for the first time. It will be operated for about 6 months at Syracuse to insure that its operational characteristics are technically feasible and to obtain results that can be used to estimate costs of capital equipment and operating costs for the direct freeze separation process in larger operations. The pilot plant will be disassembled, shipped to a seaside location to be chosen by the Office of Saline Water, erected, and operated there to obtain further information on reliability and performance during continuous operation. The work done on the development of this process since 1956 has been sponsored jointly by the Office of Saline Water and Carrier Corp.

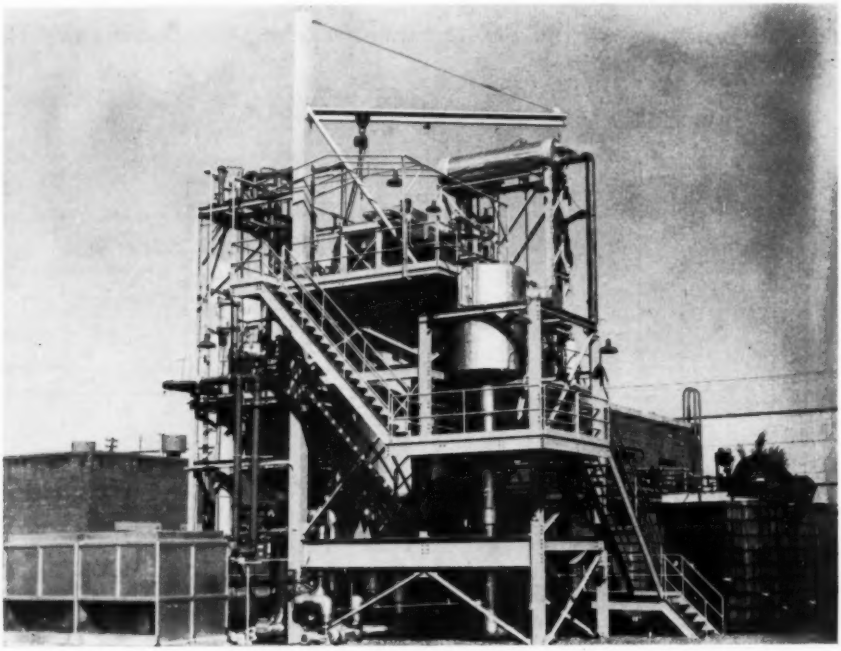

Fig. 12. Pilot Plant at Syracuse

The 15,000-gpd plant will be operated for about 6 months at Syracuse, N.Y., then disassembled and shipped to a seaside location to obtain more information about its performance during continuous operation.

Universities, research foundations, and industry in the United States, Israel, France, and Yugoslavia have

carried out research investigations of the freeze method for saline-water conversion. Studies of the method have increased markedly during the past few years. One process—being studied at Cornell University, the Blaw-Knox Co., Pittsburgh, Pa., and in Japan—is a direct freeze process, but instead of utilizing water vapor as the refrigerant, a hydrocarbon gas such as isobutane is used.

Cornell process. The characteristics of the Cornell process can be described with reference to Fig. 10. Utilizing the hydrocarbon refrigerant, the freezer will operate at 12 psia, slightly below atmospheric pressure, rather than at the reduced pressure—3.4 mm of mercury—of the water vapor refrigerant. The vapor volumes of the butane, which is vaporized to freeze the ice crystals, are considerably less than the volume of water vapor and will require less compressor capacity for compression and condensation on the surface of the ice. The condensed butane liquid, however, must be separated from the product water by a decanting-stripper cycle. The Cornell process is being studied on a small bench-scale glass experimental model.

The process, developed by Wiegandt, is based on the concept of direct freezing of sea water in contact with a hydrocarbon refrigerant, such as butane. Because the handling of butane is hazardous, methylene chloride has thus far been used as the refrigerant. Major efforts at Cornell have been directed toward the development of a satisfactory separation process. The freezing and melting stages are similar to those employed by Carrier Corp.; no problems are anticipated.

A number of separation methods have been investigated. Most of these are based on the use of a separation column, the major problem of which has been the transfer of ice slush from the generator to the separator. Failure of the ice to rise to the top of the column has also been experienced. The filtration characteristics of the ice bed have seriously limited production rates. Most recently, the hydraulic-piston method of ice bed propulsion has been found to give good results. Surprisingly, this operation is most efficient when small ice crystals are present. Work accomplished to date shows that displacement washing of small crystals is effective in producing water of very low salinity. Further studies to determine bed formation and compression from freely rising ice under conditions of hydraulic-piston-bed movement are being carried out.

Blaw-Knox process. The process currently being developed by the Blaw-Knox Co. is that of direct freezing, using butane as a secondary refrigerant. From the standpoint of cost and operation, butane appears to be a satisfactory referigerant. Because butane boils at 31°F, the freezer, melter, and washer can be operated at nearly atmospheric pressures. The formation of butane hydrate has been encountered, but, as its decomposition temperature is slightly below that at which butane is condensed, no problems are anticipated.

The Blaw-Knox process is similar in principle to that under development at Cornell. The major difference and salient feature of the process is the use of a commercially available extraction device. This unit consists of a rotor, on which is mounted a series of sector-shaped baskets, each provided with a perforated door. The rotor turns inside a vapor-tight tank. It is planned to use the device as a freezer and melter. As the rotor turns, sea

water mixed with butane is sprayed into the baskets in a given section of the tank. The ice formed is separated from the mother liquor by displacement washing. At the end of the circular path, when the perforated door of the basket is disengaged, the washed and drained ice is dumped. Ice then flows to the melter, where the heat of butane condensation converts it to product water. The butane is separated from the water by continuous decantation, heat-exchanged against sea water feed, and recycled to the butane feed tank.

The freezer is operated at 2°F below the freezing point of sea water. The melter is operated by condensing butane on the ice at 34°F. Laboratory experiments simulating washing by displacement with the rotor device have yielded ice with a salt content of less than 500 ppm. The energy consumption of the process has been calculated to be about 26 kwhr/1,000 gal.

Economic Aspect

The economic objective is to obtain water by conversion processes as cheaply as possible, so that it can be used for domestic, agricultural, and industrial uses. At the present time, it appears reasonable to expect that freezing processes will compete with other processes in reaching the objective of $0.50–$1.00 per 1,000 gal. The cost may be lower if waste heat from power plants or other processes can be utilized.

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Distillation Processes—*David M. Bradt*

A paper presented by David M. Bradt, Eng. Mgr., The J. G. White Eng. Corp., New York, N.Y.

Distillation is the oldest process that has been satisfactory for the conversion of sea water to potable water. It is the only process that inherently produces "pure" water. Very simply stated, distillation removes the pure-water molecules from sea water and leaves concentrated sea water or brine. The process is generally applied to sea water conversion because the concentration of salts in the water has a negligible effect on potability of the product water.

In all distillation processes, the same basic principle is used. Water vapor or steam is produced from sea water; then the vapor is condensed and forms fresh water (Fig. 13). The product water is generally aerated before it is made available for human consumption. Sometimes, small amounts of sea water are added to the product to produce a palatable water that contains essential minerals.

Multiple-Effect Distillation

The process used almost exclusively in large-size plants, until about 5 years ago, was that known as multiple-effect submerged-tube evaporation. In this process, each evaporator consists of a tube bundle submerged in sea water. Steam or water vapor is inside the tube bundle, where it condenses and causes the salt water to boil and thus produce more water vapor. In the multiple-effect installation, the vapor from one evaporator passes to the

next, and so on, down the line (Fig. 14). About four or five effects are the practical limit for this installation. The formation of scale has always interfered with the functioning of the evaporators, and operation has always been intermittent to allow for shutdowns for scale removal. Figure 15 shows a multiple-effect distillation plant. Several large installations with capacities in excess of 1 mgd are in existence throughout the world, but, at this time, these installations can no longer compete with some of the newer installations, either in first cost or in operating cost.

Flash-Type Distillation

As the need for fresh water has increased, the multiple-effect flash-type plant has grown in popularity. This type of plant does not boil the sea water directly on a heating surface, but raises the temperature of the water while maintaining a slight pressure on it. The heated sea water is then passed through a series of flash chambers in which the pressure is reduced step by step to a low vacuum. As the pressure is reduced, a portion of the sea water flashes into vapor, which subsequently condenses and serves to heat the incoming sea water. This condensed vapor is the fresh-water product. In recent years, large strides have been made toward increasing the efficiency of these units by the recirculation of the concentrated sea water and by various methods of scale control. Continuing research, it is hoped, will allow higher operating temperatures without scaling and permit still higher thermal efficiencies and lower conversion costs. Plants of this type are now projected to 10-mgd or larger installations. In recent years, multiple-effect flash-type plants have provided more total salt water conversion capacity than any of the other distillation processes. This process has been selected for one of the demonstration plants, and it is hoped that conversion costs in the order of $1 per 1,000 gal, based on standard cost procedures of the Office of Saline Water, will be achieved.

Long-Tube Vertical Evaporator

Recently, another new type of conversion process, in which long-tube vertical evaporators (Fig. 16) are used, has been proposed. The application

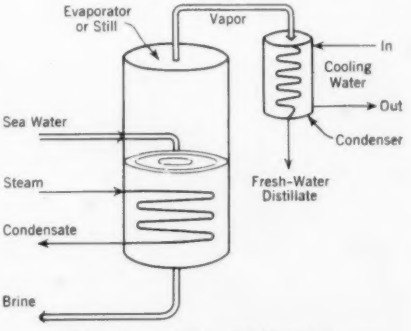

Fig. 13. Simple Distillation

Water vapor is produced from sea water and condensed to form fresh water. The product is generally aerated before being made available for human consumption.

of this evaporator to sea water conversion was first suggested by W. L. Badger as an adaptation of a process long used in the salt and paper industries. In this process, the sea water passes through the plant only once, and the retention time is quite short. In addition, a magnesium hydroxide slurry is to be circulated with the sea water. It has been demonstrated that, by the use of this technique, the evaporator can operate continuously without any scale formation. The Office of Saline Water is designing a 1-mgd demonstration

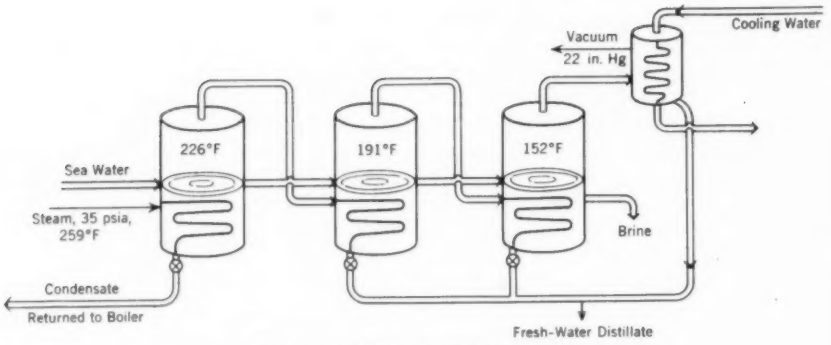

Fig. 14. Multiple-Effect Distillation

The vapor from one evaporator passes to the next one, and so on. About four or five effects are the practical limit for this type of installation.

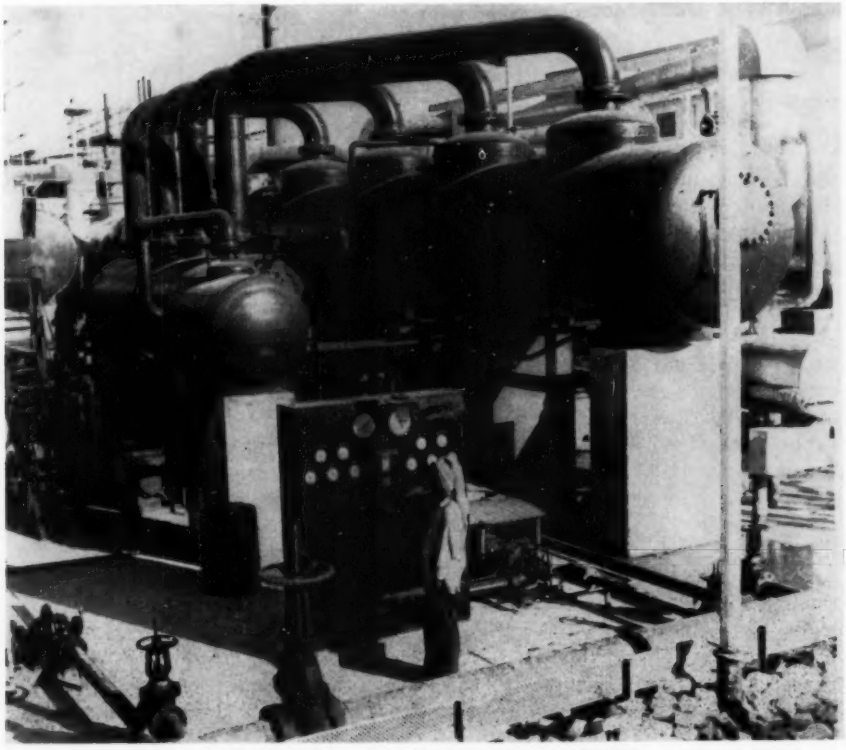

Fig. 15. Triple-Effect Evaporator at Kuwait

These installations can no longer compete with newer installations, such as flash-type plants.

plant using the principle of this evaporator. It is hoped that the plant will demonstrate that the conversion of sea water at a net cost of approximately $1 per 1,000 gal is practical in large-size plants.

Vapor Compression Plant

Another type of evaporation process that has found widespread use in units with capacities as large as 50,000 gpd is the vapor compression plant. This plant does not require any appreciable quantity of excess sea water for condensing purposes, and can be made a completely self-contained unit. In this process, the steam or vapor is compressed and then condensed in an evaporator, in which more steam is formed and in turn compressed. The only energy required is for the compressor drive, which can, of course, be either an engine, a turbine, or an electric motor. This process was used widely during the last war for small shipboard units and for isolated military units. A great deal of work is now in progress to develop large units that will operate economically on a continuous basis without scaling problems. Recent developments adapting forced circulation techniques to this process and developments using low-temperature operation, as well as methods aimed at attaining improved heat-transfer coefficients, will speed the perfection of vapor compression plants. Advances in compressor technology further increase the potential.

Conclusion

Distillation processes are the only ones available today for the production of large amounts of fresh water from the sea. The word "today" must be stressed, for advances in other processes also show great promise. The economics involved in distillation processes can lead to a never ending discussion. Suffice it to say that at this time the cost of the processes is not as low as the cost of piping fresh water for many miles, if a source is available. The source and type of energy for the distillation process are of prime importance in economic evaluations. All of these processes can be integrated with power-generating or process facilities, thereby increasing the economic advantage.

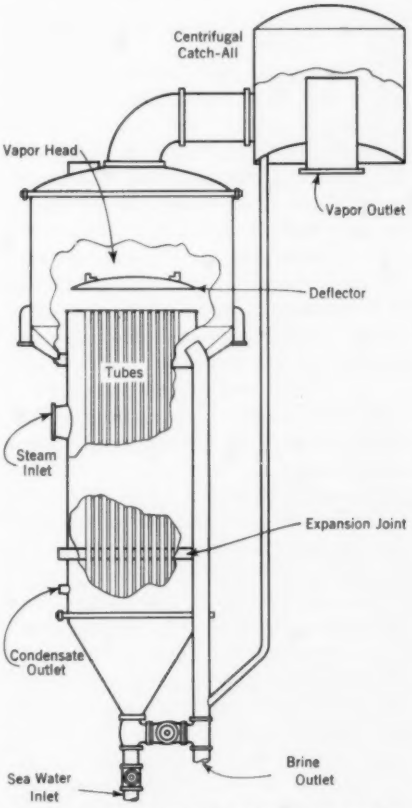

Fig. 16. Long-Tube Vertical Evaporator

The Office of Saline Water is designing a 1-mgd demonstration plant that will utilize the principle on which this evaporator operates.

Solar Distillation—George O. G. Lof

A paper presented by George O. G. Lof, Research Assoc., Resources for the Future, Washington, D.C.

Several factors make it convenient to separate a discussion of solar distillation from a discussion of distillation by conventional processes using fuels. In addition to the difference in the type of energy employed, there are large differences in equipment design, operating requirements, and the economic aspects of the processes. Similarities between solar and conventional distillation methods are really no greater than those between solar and nonevaporative systems.

The characteristics of solar energy make it both favorable and unfavorable for process purposes. Although this energy is universally available in enormous quantity, it is intermittent and at a low intensity level. The solar energy reaching the United States is about 1,700 times as great as the total energy requirements of the country. Its average daily intensity is approximately 1,500 Btu/sq ft across the nation; in the Southwest, the average approaches 2,000 Btu/sq ft. Maximum hourly energy is about 300 Btu/sq ft, a very low heat transfer rate in comparison with 100,000 Btu/hr/sq ft commonly employed in steam boilers and other equipment. It is at once evident that large surfaces must be provided for the collection of solar energy and for its delivery as heat. Therefore, it is necessary to minimize the cost of such heat transfer surfaces if the fixed costs on the investment are to be within practical limits.

General Principles

As in conventional distillation, there are three essential parts to a solar distiller: the heat supply unit, the evaporator, and the condenser. In solar distillation equipment, these components may be separate, or they may be partially or completely combined into a single unit.

Single-effect or multiple-effect evaporators of conventional type may be operated by means of steam or another heat source produced in some kind of solar heating unit. The temperature requirements for such a heat source are not severe, in many instances being somewhat less than, or at least approximately that of, the normal boiling point of water. A solar heat collector suitable for these temperature levels comprises a black, heat-absorbing metal surface in contact with small tubes through which water or some other fluid is circulated, and above which one or more transparent surfaces of glass or plastic are supported. Solar energy is absorbed on the black surface and conducted to the circulating fluid, thereby increasing its temperature or vaporizing it. The transparent covers reduce the rate of heat escape to the atmosphere, and insulation on the bottom of the collector panel minimizes heat loss. In a sunny climate, solar collection efficiencies approximating 50 per cent of the incident energy can be achieved under these conditions.

Another device for producing steam by means of solar energy is a focusing reflector that concentrates solar energy on a smaller target, which is itself a heat transfer unit in which steam or heated fluid may be produced. Higher temperatures are possible with such a system, at comparable efficiencies, but

the unit must be moved to follow the apparent motion of the sun.

Both the above types of solar collection equipment have been extensively tested and have been proved capable of generating heat at temperatures necessary for water distillation in conventional equipment. It has been found, however, from previous studies of solar distillation economics that the cost of solar collector equipment, particularly of the focusing type, is too great for competitive heat supply in the United States. Instead of typical heat costs—in large quantity about 50 cents per 1,000,000 Btu—amortization of solar equipment at presently estimated construction costs would be several dollars per 1,000,000 Btu. And because there would be no savings in distiller plant investment, economic comparison must be based on heat costs alone. Moreover, unless some form of heat storage were provided, the distillation plant could operate only during sunny hours. With such a low load factor on expensive equipment, demineralized water would be even more expensive, because much of the time the distillation plant would be idle. Thus, the supply of solar heat to a conventional plant does not appear economically practical.

Combination Units

Solar collector and water distiller. If solar energy is absorbed directly in salt water or on a surface in contact with the water, evaporation can be carried out in the solar unit itself. The resulting vapor may be delivered to an external water-cooled condenser, and distilled water will be produced. In such an arrangement, the costly evaporation plant is eliminated by the solar-energy collection system.

There are several designs by means of which this combination process can be accomplished. A shallow basin provided with a heat-absorbing cover, such as black metal, can be employed. The mixture of water vapor and air in the space between the water surface and the cover can then be circulated to an external condenser, the air being recycled to the distiller. A transparent cover may be used instead of the opaque cover, with a black, heat-absorbing surface in contact with the salt water. In another arrangement, the water itself may be colored with a dye to absorb the energy. Circulation of the vapor-air mixture to an external condenser results in fresh-water production. It would also be possible to operate a distiller of this type at the boiling point of water, thereby eliminating air from the vapor mixture. But such an operation would require the use of several layers of transparent-covering surface to achieve the desired temperatures at satisfactory efficiency.

Several distillers of this type have been tested, and some of them may ultimately prove practical. But the potentialities of a similar combination, which involves no external condenser, appear considerably greater.

Solar collector, distiller, and condenser. There are two principal systems of solar distillation which provide all the essential operating functions in one piece of apparatus. These are the basin type and the tilted, or wick, type.

Although water distillation in a solar-basin still is an old process, improvements in equipment design, resulting chiefly in the minimization of construction costs and extension of service life, have been quite recent. This type of distillation unit (Fig. 17) comprises essentially a shallow basin of salt water, the bottom of which is comparatively black, and above which sloping transparent surfaces of glass

or plastic are provided. The transparent surfaces slope downward into small channels or troughs at the sides of the long, narrow basins. Connections are provided for a supply of salt water to the basin, overflow of brine from the basin, and drainage of distilled water from the collecting troughs. In operation, solar energy is absorbed on the black bottom of the basin, and the salt water is warmed to temperatures as high as about 160°F. Water vapo-

continuously or intermittently added to make up for evaporation and brine discard.

If a shallow layer of water is employed—typically about an inch deep—the water is cold at sunrise, and during the first 2 or 3 hours of the day, its temperature rises without much distillation. Through the middle part of a sunny day, the water temperature is 150°F or more; evaporation from the basin takes place, and the vapor con-

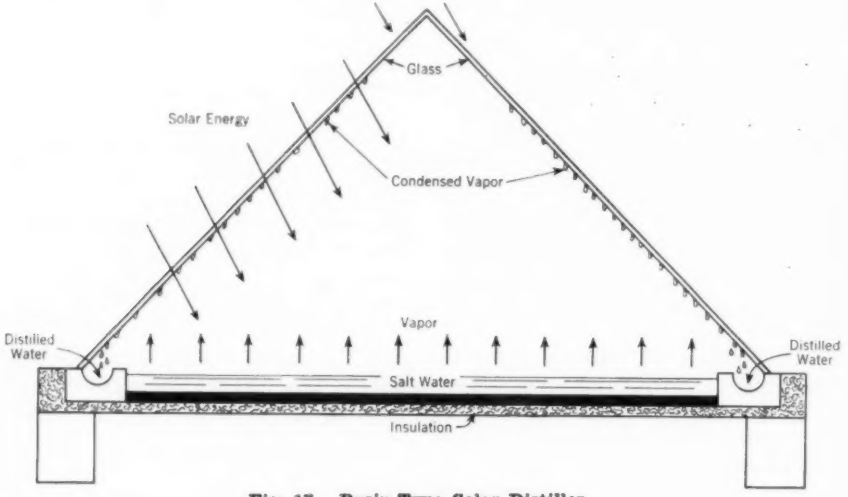

Fig. 17. Basin-Type Solar Distiller

The transparent surfaces slope downward into small channels or troughs. The condensate runs down the sloping surfaces, into the troughs, and out to storage. A portion of the unevaporated salt water is run to waste, to prevent salt deposition in the basin.

rizes into the air space above the pond and, instead of circulating to an external condenser as previously described, condenses on the cooler, transparent cover surfaces. In effect, an air-cooled condenser covers the distiller basin. The condensate runs down the sloping covers into the troughs and out to storage. Unevaporated salt water is drained from the basin and discarded. Salt water feed may be

denses on the transparent covers at 100°–120°F. The rate of evaporation decreases as the sun drops lower in the sky in the late afternoon; the water temperature goes down; and distillation ceases at about sunset or shortly thereafter. Typical water production rates in a well designed distiller may be 0.1–0.15 gpd/sq ft at solar intensities of 2,000–2,600 Btu/sq ft/day. This distillation rate is equivalent

roughly to about 50 per cent efficiency in converting solar radiation to heat for water vaporization.

If a deeper layer of salt water is used—about 1 ft, for example—the water temperature does not change nearly as much during the 24-hr period, nor does it get as high as in the shallow-basin distiller. Because considerable heat is stored in the deep pond of water, distillation continues after sunset and through the night, accompanied by a basin temperature decrease of a few degrees. On the following day, the water temperature again rises as distillation proceeds. As a result, distilled-water production is more uniform throughout the 24-hr period, but the total quantity of distilled water produced is not significantly different from that produced by the shallow still. In other words, a 50 per cent solar utilization efficiency may be roughly applied to this type of distiller also.

The advantages of the deep basin are its simplicity, durability, and low-cost potential. Because it is constructed of common building materials, directly on the ground, standard construction techniques can be employed. No insulation is required beneath the basin, because the ground acts as a heat storage system of infinite capacity, absorbing and returning heat by temperature changes near the ground surface.

A variation in the shallow-basin design that has received important attention recently is one employing plastic films for basin and cover surfaces. A thin black film, such as polyethylene, may be draped over low retaining walls to form a shallow, watertight basin over which a durable polyester film * may be employed as the transparent cover. By means of internal supports or by simple air inflation at low pressure, the transparent cover film can be maintained in a comparatively firm and smooth contour over the basin. The operation of this distiller takes place in a manner similar to that previously described. As in the deep-basin design, construction directly on the ground, without bottom insulation, appears to be the most practical design.

In effect, the wick type of solar distiller is a basin still tilted to face the sun more directly. Continual movement of the distiller to face the sun has generally not been attempted; instead, the distiller has been tilted to the south at a favorable, fixed position. A surface thus oriented, in the southern part of the United States, will intercept 5–10 per cent more radiation in the summer and as much as twice as much radiation in the winter as the equivalent horizontal area. Thus, additional energy per square foot of heat-absorbing surface is available for evaporation.

The maintenance of a wetted black surface has been accomplished by use of a fabric stretched or otherwise supported on a tilted frame, to which salt water is fed at the proper rate. Evaporation from the black, porous surface occurs when it is irradiated by the sun; water condenses on the transparent covering window and, in some designs, also on a transparent or opaque surface behind the wick. Similar results have been secured in a tilted still in which saline water is maintained on a sloping, hard, black surface by use of low ridges or recesses to retain water on the surface and to permit its slow travel to the lower edge of the inclined evaporation area. Still another design provides vertical wicks in a plastic-film envelope-type enclosure.

The combination of solar collector, distiller, and condenser, of basin and

* Such as Weatherable Mylar or Teslar, manufactured by E. I. du Pont de Nemours & Co., Wilmington, Del.

tilted types, has a distinct economic advantage over the separate components previously described. First, the quantity of equipment is minimized. Second, the materials of construction are inherently inexpensive, because they are essentially building materials rather than elaborate mechanical and process apparatus. Third, with no moving parts, maintenance and operation should require very little expense. In particular, the excessive cost of an idle evaporator and condenser plant is avoided. Fourth, unskilled labor, both for construction and operation, is adequate, an advantage particularly important in some foreign countries where skilled personnel are unobtainable.

Certain disadvantages are also evident in the combination units. There appears to be no practical method for securing multiple-effect evaporation, at least with present designs. This limits the productivity of these units to approximately 0.1 gpd/sq ft, or roughly 4,000 gpd per acre. The large area requirement for sizeable water production is, therefore, a second disadvantage, common, however, to all types of solar-operated equipment.

In addition to the basin and wick types of solar still, several others have been investigated. One of these employs a multiple-effect principle through the use of several wick assemblies in a stack. Solar-distilled water from the first wick surface serves as the heat supply to the second, and so on. Another design involves the vaporization of water through a porous plastic film that is permeable to vapor but not to liquid. These and several other new concepts are not sufficiently well developed to permit economic evaluation, but efforts are being made to develop these designs.

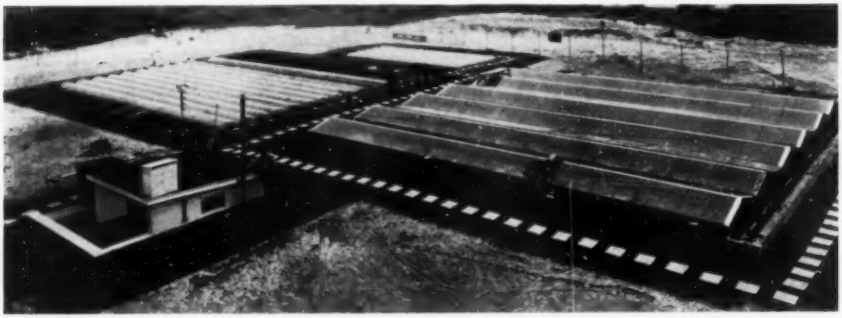

Fig. 18. Solar Research Station at Daytona Beach

At this station in Florida, different solar distiller units are being tested. On the right in the photograph are deep-basin, glass-covered distillers. On the left are the inflated, plastic-covered distillers.

Economic Problems

The foregoing discussion shows that the technology of solar distillation of saline water is comparatively simple and well developed. Although modest increases in efficiency may yet be achieved by technical improvements in materials and design, the primary requirement appears to be a reduction in the cost of distiller construction. This is being approached in two ways. One effort is exemplified by the plastic-film units described above, which involve significantly lower material costs and

moderate labor expense for construction. These materials and techniques will probably permit a minimum investment in solar distillers. Amortization of the investment over the expected life of the equipment should result in water production costs competitive with the best demineralization methods.

The other approach to maximum economy is typified by the deep-basin still, in which only very durable materials are utilized in the simplest and cheapest possible design. Although the deep-basin still is initially more expensive than the plastic distiller, its longer service life puts it in the same economic range as the plastic distiller per unit of output. Undoubtedly, both basic designs can be further simplified, and, possibly, some of the wick types may prove useful, particularly in small, family-size distillers.

It is extremely difficult to make confident predictions on the cost of solar-distilled water, because, as yet, no large plants have been built, and the construction costs on the several types undergoing tests have not been well established. As very rough estimates, however, the following figures may be considered. In a sunny climate, about 30 sq ft of a basin distiller is required for the annual production of 1,000 gal of distilled water. If a durable distiller can be built for $1 per square foot, if a 50-year life can be achieved, and if maintenance is practically negligible, amortization of the plant at 2 per cent per year, and other fixed costs at 4 per cent, would place the cost of solar-distilled water from such a unit at $1.80 per 1,000 gal. If the distiller can be built in very large sizes for little more than the costs of materials themselves, by virtue of large-scale construction economies, a potential cost of $1 per 1,000 gal can be predicted. With preassembled plastic-film distillers, construction costs of less than 50 cents per square foot can be foreseen. The durability of these materials under practical operating conditions is uncertain, but if a 10-year life and a construction cost of 25 cents per square foot in very large quantity are assumed, amortization and fixed charges would be about $1 per 1,000 gal.

As is evident from the costs of other processes, these prices are competitive, and, in some situations, solar distillation might be the most economical method. Much development work has to be done, however, before the low costs can be realized. To this end, several development programs in the United States and abroad are in progress.

Development Programs

Several solar distillation development projects have been carried forward by the Office of Saline Water since the establishment of the program in 1952. Most of these studies have been directed toward the development of basin-type and wick-type solar distiller plants and the evaluation of these in relation to other demineralization methods. Early in 1958, a field station for testing the more promising designs was established by the Office of Saline Water at Daytona Beach, Fla. Battelle Memorial Institute was engaged to operate the pilot plant installation.

At the present time, three solar distillation plants are being tested at the Daytona Beach field station (Fig. 18): a 2,500-sq ft, glass-covered, deep-basin still, essentially as described above; a 2,500-sq ft distiller, employing polyester film * for the transparent cover surface; and a small, 500-sq ft plastic still in which another polyester film † is used. The deep-basin, glass-covered

* Mylar.
† Teslar.

still is provided with side walls and basin partitions of concrete block, glass supports of redwood and gaskets of neoprene, and bottom liners of prefabricated asphalt slabs. In the two plastic stills, low curb walls of concrete block are used, and black polyethylene film forms the basin bottom. The transparent covers are supported by slight air pressure supplied by a small blower.

These first units are undergoing considerable modification while testing is in progress. Only preliminary results of performance are now available, and, in general, they confirm the estimates made. Plans for continuing this program involve further performance testing, complete thermal analyses that will permit evaluation, for the first time, of the various heat losses occurring in these solar distillers, determination of maintenance requirements and the probable useful life of these units, and studies of design changes and improvements leading to more economical construction and increased productivity.

Also planned at the Daytona Beach test station is the construction of two or more additional solar distillation units of the tilted-wick type and the vertical-wick type enclosed in plastic. These will be comparatively small units, but of a size adequate for evaluation of relative productivity and operating requirements. If other modifications or designs are developed and seem promising as potential low-cost water producers, they will be field tested at this installation also.

As part of a comprehensive saline-demineralization investigation, California has sponsored solar-distillation studies at the University of California for several years. Numerous small distillers have been built and tested at that institution. Most of these are similar to those being developed by the Office of Saline Water.

Considerable work in this field is being done abroad, particularly in Algeria and Australia. The emphasis there is on small solar distillers capable of supplying drinking water for an average family or for a few domestic animals. Commercial units of 1–5-gpd capacity are being produced in both countries for rural use, particularly for distillation of brackish ground water. They are of a type employing a 15–30-sq ft asbestos-cement basin and sloping glass covers.

Future Prospects

Although solar distillation of saline water is an old process, very little modern design work has been applied to this system. In the few years since the saline-water program was initiated in this country, substantial advances toward an economical solar distillation process have been made.

No demineralization process, including solar distillation, can be expected to produce water at costs competitive with naturally occurring fresh water at most locations. There now are situations, and these will multiply in the years ahead, where even expensive water is in demand. There is every reason to expect that in sunny climates, particularly in certain foreign countries where fuel is comparatively expensive, solar distillation of sea water will be an important process for demineralization. It is possible that small family-sized units may be widely used in some of these areas. When designs have been further simplified and economies achieved, plants with large capacities should begin to appear, probably first in foreign countries. And in the arid and sunny climates of southwestern United States, and in some of its territorial possessions; solar distillers can be expected to become a significant part of the water supply system.

Domestic Water Supply Demineralization at Coalinga

Edmund S. Cary, Henry J. Ongerth, and Reginald O. Phelps

A paper presented on Oct. 30, 1959, at the California Section Meeting, Bakersfield, Calif., by Edmund S. Cary, Sr. San. Engr., California State Dept. of Public Health, Fresno, Calif.; Henry J. Ongerth, Sr. San. Engr., California State Dept. of Public Health, Berkeley, Calif.; and Reginald O. Phelps, Director of Public Works, Coalinga, Calif.

COALINGA, Calif., with a population of approximately 6,300, is located in a small valley, at an elevation of 671 ft, almost surrounded by low, barren hills. The average maximum summer temperature is 103°F. The annual average rainfall is 7 in. The ground water table is fed from the Coast Range Mountains, and the water is very hard and unpalatable.

The Southern Pacific Railroad came to Coalinga in 1887, long before the incorporation of the city. Soon after the coming of the railroad, drinking water was hauled to Coalinga by rail tank cars. For several years, the water was dumped into an underground cistern and then pumped with a hand pump and sold for 10 cents a bucket. This old cistern, abandoned about 55 years ago, is still visible today. After the abandonment of the cistern, drinking water was hauled by horse and wagon to each home and stored in an 80-gal tank in the front yard. On hot summer days, the water would get very warm.

The city acquired both hard- and soft-water systems from private interests in 1917. In 1923, a soft-water storage tank was built on a tower. Water was pumped from the railroad tank cars to the tower and then distributed by tank truck to homes. During this time, the city was drilling deep wells within the city limits to expand the hard-water system, but always with the hope that a potable soft-water supply would be found locally.

In 1926, city crews began building a soft-water distribution system, paralleling the existing hard-water system. It was not until Jan. 1, 1931, that the tank truck distributor was retired, and every house was connected to the soft-water mains. These mains are 0.5–2 in. in diameter. For the last 28 years, soft water has been brought in by railroad from Armona, Calif., most recently at a cost of $7.05 per 1,000 gal at the rail head. This Armona water is an excellent tasting, soft water, sold to the consumers for about a cent a gallon. The average per capita use of the water is about 3 gpd. At most homes, this water is piped to a single tap at the kitchen sink and is used primarily for drinking and cooking.

Plant Costs

The high cost of the soft water and the inconvenience of handling it by tank car was the reason for acquiring a demineralization plant. Two years

ago, the city learned of a demineralizing process developed by Ionics, Inc., Cambridge, Mass., and invited the company to evaluate the possibilities of demineralizing its hard-water supply. The company agreed to set up a pilot plant so that the process could be demonstrated to produce a water of acceptable potability. The pilot plant was operated in Coalinga for 3 months in 1958. During this period, people were invited to taste and use the demineralized water and to compare it with the Armona water available from an adjacent tap. The pilot plant performed as predicted, and the general public reaction was favorable. As a result, the city entered into a contract with the company for the installation of a full-scale, 28,000-gpd (20-gpm) plant.

The cost of the plant was more than $80,000. The city, rather than sell bonds to pay for the project, entered into a lease-purchase arrangement with the company, and is now renting the unit (plus certain accessories not covered by the original offer) for $2,500 a month. This rent may apply on the purchase price. At the end of a 30-month option period, the city can buy the plant by paying a balance of $21,000. With this arrangement, the full cost of the treatment equipment installed, plus all interest charges, will be $96,000. The total cost to the city for the treatment facility, including

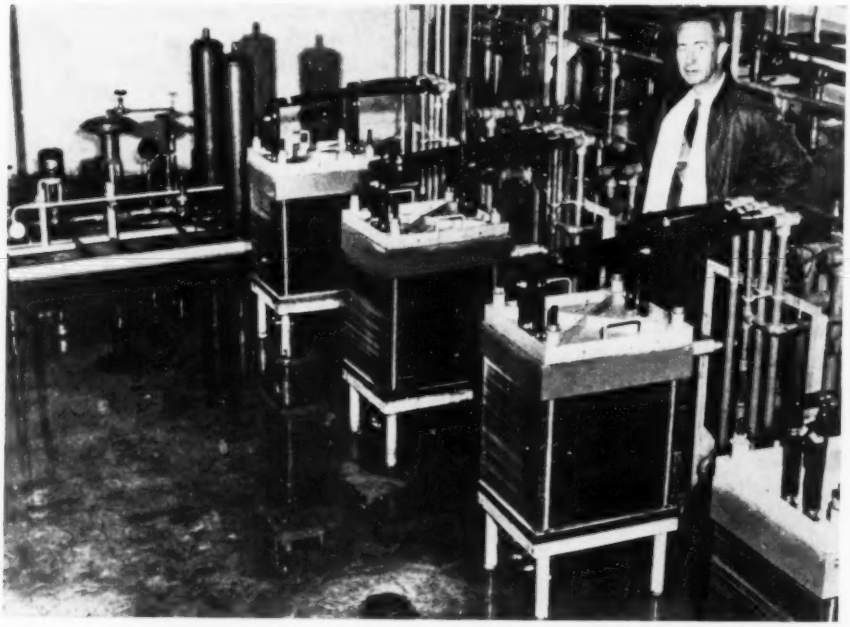

Fig. 1. Interior of Demineralization Plant

Four demineralizer units (stacks) are shown in the foreground. The raw-water inlet, control valves, pressure control, and cartridge filters are shown at the far left.

building, installation, and connection charges, is $105,000.

The city also has a contract with the company for service and replacement parts, at a cost of $350 a month. Under this contract, the city is entitled to two service calls a year from a company engineer, plus the right to purchase additional or emergency service and all stack replacement parts at half price.

Equipment and Process

The process of electrodialysis employs a unique application of ion-exchange resins for removing minerals from water. The equipment used in a demineralization plant (Fig. 1) includes: one or more demineralizer units, electrical equipment, pumps, chemical-feed equipment, filters, and hydraulic and electrical controls. A demineralizer unit is known as a "stack," which may be thought of as a many-layered sandwich (Fig. 2). Each pair of one type of layer represents two different kinds of ion-exchange membrane sheets that are permeable on a selective basis ("permselective")—that is, permeable to charged ions under certain conditions and impermeable to water. One membrane is permeable to positive ions (cations); the other, permeable to negative ions (anions). The other types of layers are spacers with channels cut in them; one spacer for water being demineralized, the other spacer for waste water.

Water passes through the spacers in parallel. There are 150 sets of layers in each stack, which is usually 21 in. high, with 18×20-in. membranes and spacers (Fig. 3). The top and bottom layers of this large sandwich are metal anode and cathode sheets, the negative and positive poles of the electrical system. The driving force is direct current. At Coalinga, the current is obtained by passing the community alternating current through a rectifier. An installation may consist of one or more stacks, operated in series or in parallel. At Coalinga, four stacks are operated in series. Table 1 shows the voltage and current used.

The ion-exchange sheets are solid plastic, approximately 0.030 in. thick. The spacers are polyvinylchloride plastic sheets, approximately 0.040 in. thick. The anode sheets are tantalum, coated with platinum, and the cathode sheets are a high-temperature, nickel-base alloy.*

TABLE 1

Stack Voltage and Current

Stack Number	Voltage *v*	Current *amp*
1	225	11
2	185	7
3	160	5
4	130	3

Operations

When a direct current flows through the stack from cathode to anode, ions are attracted toward their opposite pole, pass through the membrane selective for them, into the adjacent waste channel, and are concentrated in this channel. Water to be demineralized is pumped to each stack in series. The water loses about 40 per cent of its mineral content through each stack. Theoretically, 87 per cent of the minerals should be removed by four stacks. The average removal of minerals through four stacks at Coalinga is about 83 per cent. It should be noted

* Hastelloy C, manufactured by Haynes Stellite Co., Division of Union Carbide & Carbon Corp., New York, N.Y.

that percentage removals vary among various elements (Tables 2 and 3).

The electrodialysis process is sensitive to stack temperatures. Higher temperatures increase capacity; lower temperatures decrease capacity. Temperatures greater than 120°F will reduce the life of the membranes.

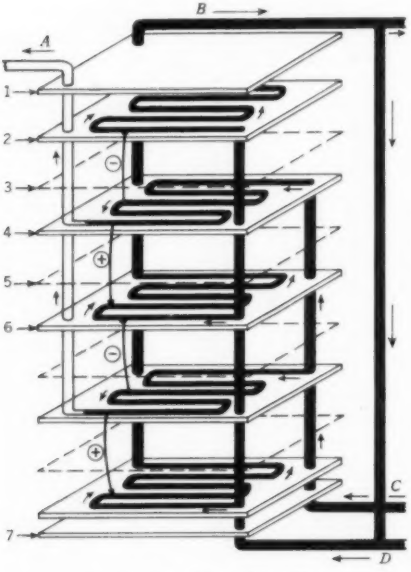

Fig. 2. Demineralizer Unit

Stack parts: 1, *anode plate;* 2, *waste-water spacer;* 3, *anion membrane;* 4, *product-water spacer;* 5, *cation membrane;* 6, *waste-water spacer; and* 7, *cathodic plate. Pipe:* A, *product;* B, *waste-water discard;* C, *raw water; and* D, *diluting water.*

The plant is equipped with a number of automatic protective devices that shut down the unit or activate a warning bell in the event of: (1) high or low pressures; (2) high feedwater temperature; (3) power failure; and (4) failure to reach desired product salinity, as measured by an electrical-conductivity cell. This automatic equipment is designed to prevent operations under conditions where temporary or permanent damage to the unit might result, and to prevent entry of raw water into the treated-water system.

Because the flow passages within the spacers are narrow, any significant amount of suspended solids must be removed from the feedwater. Furthermore, organic solids may create slimy coatings on membrane surfaces. For these reasons, raw water is filtered, using cartridge-type industrial filters † with a maximum pore size of 5μ.

Because the saline waters contain large concentrations of carbonates, acid is added to the waste-water stream to maintain a negative Langelier index, in order to prevent encrustations from occurring within the stack. Encrustations or the accumulations of particulate matter cause "hot spots" in the adjacent membrane which can damage or destroy that membrane. Hot spots become areas where the membrane dries out and electrical resistance rises abruptly, ultimately destroying the proper function of the stack. These areas may be readily detected by use of a portable voltmeter, with a pair of probes held a fixed distance apart on the vertical side of the stack. An abnormal area in the stack will show a large voltage drop.

Waste water from this plant is produced at the rate of 0.5 gal for each gallon of treated water produced. Disposal of this waste water is no problem at Coalinga, for it is added to the secondary, hard-water reservoir. This addition is not appreciable, because the waste flow is much smaller than the hard-water flow. In some areas of California, waste-water disposal from a

† Manufactured by Cuno Engineering Corp., Meriden, Conn.

demineralizer might require other techniques. Among those that have been suggested are: (1) ponding and evaporation; (2) injection through wells into deep saline aquifers; (3) hauling or piping to such acceptable disposal sites as the ocean, or dry, saline lake beds; and (4) dilution with raw water or sewage plant effluent from the town served with demineralized water, followed by agricultural use, recharge, or stream disposal of the blended water. The preferred method depends on the size of the demineralizer, geographic location, climate, the hydrology and geology of the area, land use in the vicinity of the plant, and, perhaps most important of all, the total mineral content of the raw water.

The Coalinga plant has been operating under a permit from the state department of public health. Operation has been closely watched by the department, and a testing program has been conducted to determine the chemical and bacteriologic condition of the drinking water produced. There has been a problem of finding adequate bacteriologic sampling points within the plant; apparently, the equipment does not support the production of coliform bacteria. Chemical analyses have been made on daily samples of raw and treated water composited either weekly or monthly. Table 3 shows the average of the chemical analyses made on these samples; Table 2 shows the analyses in detail. It can be seen from these analyses that less than 10 per cent variation has occurred in the samples of raw water. Treated water varied in total solids from 367 ppm in February to 470 ppm in April, with an average of 402 ppm. Daily vari-

TABLE 2

Analysis of Raw- and Treated-Water Samples

Month—1959	pH	Minerals—ppm													
		Total Solids	Hardness (as $CaCo_3$)	Alkalinity (as $CaCo_3$)	Cl	SO_4	F	No_3	Ca	Fe	Mg	Na	Mn	K	B
	Raw Water														
Feb. (3–9)	8.2	2,390	570	138	258	1,142	0.6	1.1	108	0.1	73	524	0.05	8.3	4.9
Feb. (10–16)	8.3	2,385	545	138	262	1,122	0.6	0.6	106	0.00	68	509	0.00	8.6	4.2
Feb. (17–23)	8.0	2,426	578	144	266	1,179	0.2	0.7	111	0.00	73	520	0.00	8.8	2.7
Mar.	8.0	2,380	574	142	257	1,172	0.2	0.7	114	0.00	71	510	0.00	9.0	2.6
Apr.	8.2	2,376	595	144	252	1,170	0.2	0.9	120	0.00	72	500	0.00	9.4	2.8
May	8.0	2,395	579	142	260	1,173	0.2	0.8	116	0.00	70	520	0.00	9.2	2.7
Jun.	8.1	2,394	580	138	244	1,145	0.5	1.3	118	0.4	70	500	0.05	9.0	3.1
Avg	8.1	2,392	574	141	257	1,158	0.4	0.9	113	0.1	71	512	0.02	8.9	3.3
	Treated Water														
Feb. (3–9)	7.8	367	36	28	13	174	0.0	0.0	5.2	0.0	5.6	91	0	0.6	2.5
Feb. (10–16)	7.3	406	38	26	12	208	0.0	0.0	6.0	0.0	5.6	103	0	1.9	3.6
Feb. (17–23)	7.6	378	34	24	12	192	0.1	0.0	6.0	0.0	4.7	75	0	0.8	2.7
Mar.	7.8	389	32	30	15	160	0.1	0.0	6.2	0.0	4.0	87	0	0.8	3.0
Apr.	7.7	470	53	31	24	238	0.1	0.0	9.6	0.0	7.1	120	0	1.2	2.8
Jun.	7.3	400	33	24	13	195	0.1	0.1	6.0	0.4	4.3	98	0	1.0	2.8
Avg	7.6	402	38	26	15	195	0.1	0.0	6.5	0.1	5.2	96	0	1.1	2.9
Armona*	8.5	215	40	95	21	7.1	1.0	0.1	1.6	0.0	0.0	61	0	0.4	

* Soft water from Armona, Calif.

ations have been larger, but, with a use of only 18,000 gpd and a storage capacity of 75,000 gal, the consumer receives a relatively uniform water.

The treatment works are operated under the direct supervision of the director of public works. Day-to-day operations consist of changing filters, mixing acid and soda ash, keeping daily log sheets, and keeping the building clean. The city mechanic, with some assistance, conducts flushing operations and the cleaning of stacks. When a stack is to be cleaned, it is taken off

Fig. 3. Assembling a Stack

The man on the left is holding a membrane sheet. A spacer sheet is on top of the stack. An anion membrane, a product-water spacer, a cation membrane, and a waste-water spacer make a set of layers; there are 150 sets of layers in each stack. The height of a stack is usually 21 in., with 18×20-in. membranes and spacers.

operation is done by selected men from the adjacent firehouse, assisted and directed by the city mechanic for major maintenance and operational procedures. These persons have been trained by the company that supplied the equipment. There is always one man available in case of trouble; others are available when needed. Routine the line and completely disassembled. Each sheet of the stack is then carefully cleaned with a stiff brush to remove encrustation, flushed thoroughly, and reassembled in the stack. Firehouse personnel aid in this operation. All personnel have been trained to start the unit. About an hour a day is necessary to perform the routine operational pro-

cedures. It takes two men 4.5 hr to tear down, clean, and reassemble a stack. Stack maintenance was originally estimated to be necessary every 3 months. The experience during the past 6 months has indicated that Stack 1 may have to be cleaned monthly, because it has the greatest amount of deposition. The stack and the system are chlorinated after each cleaning.

The plant is run continuously, although it was originally planned to be operated intermittently. Because the start-up procedure is rather tedious, and because the savings from intermittent operation are relatively small, continuous operation was initiated. Excess treated water is diverted to the nearby hard-water reservoir. At approximately 3-day intervals, the unit is flushed by turning off the electric power and allowing water to recirculate for 8 hours through the stacks and into the nearby hard-water reservoir. This procedure apparently releases the static electrical charge of the accumulated particles in the stacks and allows them to be flushed to waste, materially increasing the time interval between cleaning of stacks.

pH Control

Prevention of calcium carbonate deposition in the waste-water spacers is an important factor with regard to the life of the stacks. Acid is therefore added to the waste-water stream so that the pH is maintained in the stream at 6.1, slightly less than the pH of calcium carbonate saturation, as determined by the Langelier index. An acid electrode-flushing stream, not previously described, is maintained at a pH of 3.2 to keep the electrodes free of deposition. About 2 lb of sulfuric acid is used per 1,000 gal in this pH control.

The raw water has a pH of about 8.1. The treated water, as it leaves the unit, has a pH of about 6.5. A positive Langelier index is maintained by the introduction of soda ash into this product stream after treatment. The pH of this water in the system is 7.6.

Power Costs

The city purchases power through a master meter connected to all the pumping units in the city. Moreover, power unit costs depend on total electrical consumption, month by month. Therefore, although the treatment unit uses power at a constant rate, the cost of the power varies from about 1.3 cents to 1.9 cents per kilowatt-hour. The average cost during the first 6 months was 1.5 cents per kilowatt-hour. The pilot plant power consumption was about 12.3 kw/1,000 gal. During the first 6 months, however, the power usage averaged 14.2 kw/1,000 gal. The power cost has averaged 21.46 cents per 1,000 gal.

TABLE 3

*Composite Analysis of Raw- and Treated-Water Samples, February–August 1959**

Water	pH	Minerals—*ppm*				
		Total Solids†	Hardness (as $CaCo_3$)	Cl	So_4	B
Raw	8.1	2,392	574	257	1,158	3.3
Treated	7.6	402	38	15.0	195.0	2.9
		Minerals Removed—%				
		83.2	93.4	94.4	83.2	12.1

* Average values.
† Residue on evaporation.

Deposition Problems

The city has encountered problems of short filter life and of deposition

within the stacks during the first 6 months. The analyses of some of the accumulated matter have shown some organic material, possibly slimes. The deposition problem is attributed largely to raw water from a 4-in. dead-end main. The plant has industrial filters to protect the stacks against dirty water, but the raw water was much dirtier than anticipated. As a result, filter life was unexpectedly short. This is significant, inasmuch as the filter unit contains nine cartridges, costing $1.20 each. The city experimented with filter cartridges and found that the replacement time of these cartridges in sizes of 1–5 μ varied little. During this period, filters were replaced as frequently as once a day, with an average filter life of about 2 days. In an effort to increase filter life, the source of raw water was changed to an active main nearby. This change has increased filter life to about 3 days. The city has considered the use of a diatomaceous earth filter in series with the industrial cartridge filter. The company is suggesting the use of this type of filter in larger installations.

During the period when filter problems occurred, the deposition of particulate matter within the flow channels in the stacks interfered with stack performance by creating hot spots of high electrical resistance. This necessitated frequent cleaning of the stacks and the replacement of damaged membranes, particularly of Stacks 1, 2, and 3. Membrane life is uncertain. The supplier initially estimated the life of the membranes to be 3 years, but, on the basis of experience, the estimate has since been revised to 5 years. At Coalinga, 150 membranes have been replaced during the first 6 months of operation. Since the change in location of raw-water takeoff, this replacement rate has been materially reduced. So far, no estimate can be made for membrane life in this operation.

Operating Costs

Detailed operating records are being kept, showing power used, conductance readings, pH control, water treated, and other operational experiences. From these records, a reasonably close cost analysis is available for the first 6 months of operation.

The original cost estimates, based on the pilot plant, indicated that operating costs would be about $1 per 1,000 gal. This figure did not include labor costs, because the city is using existing personnel. Table 4 shows the water production costs during the first 6 months. The costs are well within the original estimates, despite the increased power costs and the shorter life of filter elements. The figures also include a labor cost, which is an allocated cost (there has been no addition to the city labor force for this operation) chargeable to the equipment for the time necessary for operation and maintenance. The

TABLE 4

Operating Costs, Mar. 1–Aug. 31, 1959

Item		Costs $/1,000 gal
Labor		0.1667
Chemicals		0.0625
Parts and replacement		
Membranes	0.2325	
Filters	0.1861	
Miscellaneous parts	0.0301	
		0.4487
Power		0.2146
Total		0.8925
Amortization of capital investment		0.5400
Total		1.4325
Previous cost of drinking water (Armona)		7.05

equipment and building will have cost the city about $105,000. With the use of a straight-line amortization based on actual use of water, this cost has been estimated at 54 cents per 1,000 gal.

It is anticipated that future performance of this process at Coalinga will be good. Since the change in the raw-water takeoff point, the city has realized improved filter and membrane life. This will reduce the labor required, as stacks need not be disassembled as frequently as before. As the operators learn to handle this equipment more efficiently, further savings in manpower are anticipated. Power costs, on the other hand, may increase, for the 6 months covered by these data are the months of greatest power use and, hence, lowest unit power cost. It is anticipated, despite the increase in power costs, that operating costs may be decreased by as much as 15 cents per 1,000 gal. Better filtration methods are being investigated. If this can be effected, operating costs may show a further decrease.

Summary

Because plant operation at Coalinga has not been fully stabilized, observations herein presented must be considered as tentative. On the basis of 6 months of operation and observation, the electrodialysis treatment process has been successful. The removal of dissolved minerals has been as indicated by the pilot plant tests, and at costs commensurate with those originally anticipated. Elements of cost dependent on membrane life and anode-cathode life cannot as yet be definitely determined. Removal of dissolved solids is approximately 83 per cent. It should be noted, however, that percentage removal of various mineral constituents differs. The removal of boron is almost nil, while other constituents are removed on a selective basis. The one serious operating difficulty, short filter life and clogging of the stacks, apparently resulted from providing feedwater for the plant from a relatively inactive water main. A new connection to an active main has since been installed, and the situation has been greatly improved. If water were obtained directly from the city wells instead of through a large storage reservoir, results might be even better. Daily operation of this plant, largely with unskilled personnel, supplemented by competent technical assistance from the manufacturer, has resulted in no serious problems. As far as the citizens of Coalinga are concerned, the plant is a success. The water produced has been accepted by the citizens, despite the fact that the previous supply was a high quality, exceptionally good-tasting water.

Coalinga was a favorable place to install a demineralization plant because:

1. The supply being replaced was extremely costly.
2. A separate pipe system for distribution of the demineralized supply was already in existence; it was therefore unnecessary to demineralize the entire community supply or to construct a second distribution system.
3. There is no problem in disposing of waste water.
4. The raw water contained only 2,200 ppm of total solids.
5. Power rates are moderate.

New Jersey State Water Development Program

George R. Shanklin

A paper presented on Oct. 22, 1959, at the New Jersey Section Meeting, Atlantic City, N.J., by George R. Shanklin, Chief Engr. & Acting Director, Div. of Water Policy & Supply, State Dept. of Conservation & Economic Development, Trenton, N.J.

ON Nov. 4, 1958, the people of New Jersey overwhelmingly approved, by referendum vote, the New Jersey Water Supply Law of 1958 and its companion Water Bond Act. This legislation places with the State Department of Conservation and Economic Development, through the Division of Water Policy and Supply, the authority, responsibility, and funds for the formulation and conduct of a threefold state water program to: (1) insure, through long-range planning, the availability of adequate future supplies in all parts of the state; (2) insure, through long-range intensive investigations, the protection and orderly development of statewide ground water resources; and (3) provide, as authorized, the new water required to meet the critical demands of the northern metropolitan area by the design, construction, and operation of storage facilities to augment the natural surface water resources of the South Branch Raritan Basin. The $45,850,000 bond issue authorized by the referendum provides funds (not to exceed $39,500,000)—when satisfactory assurances are obtained by the commissioner of conservation and economic development, relative to the net income to be derived from the sale of water—for the construction of: (1) a 55-bil gal off-river storage reservoir in Round Valley, including diversion works required to fill the reservoir with water from the South Branch Raritan River, and (2) an 11-bil gal reservoir on Spruce Run Lake for stream flow regulation and sale of water from the river. These two storage facilities are designed to meet the immediate and near-future water demands of the northeastern metropolitan and Raritan Valley areas. Also included in this bond issue are:

1. $1,250,000 for an intensified, statewide, long-range ground water investigation for report by counties and special programs

2. $100,000 for study, tests, construction, and operation of a pilot plant to evaluate the practicability and suitability of developing and utilizing the natural ground water storage in the Pensauken formation on the upper Millstone Basin to supplement on-river storage as a source of water supply

3. $3,000,000 for continued study and planning for the most economical development of the surface water resources of the Raritan and Millstone river basins, including acquisition of property when authorized, to designate reservoir sites essential therefor and to insure availability of these sites when required for construction

4. $2,000,000 for similar studies and planning for the development of the

surface water resources elsewhere within the state, including acquisition of property when authorized.

The Spruce Run Lake Reservoir is an on-river, 11-bil gal stream flow regulation reservoir located on Spruce Run and Mulhockaway Creek, northwest of Clinton in Hunterdon County. The reservoir will provide release flows to maintain the statutory, sustained, low flow requirements in the Raritan River and its south branch for nonconsumptive uses; plus an additional, sustained minimum flow, equivalent to 60 mgd at the Bound Brook gaging station, for sale or allocation of water from the river for potable supplies and industrial, irrigation, and other consumptive uses.

The Round Valley Reservoir is an off-river, 55-bil gal storage reservoir located in a natural bowl site south of Lebanon, also in Hunterdon County. The reservoir will be filled by pumping water from the South Branch Raritan River, through 3.3 mi of force main, and will provide the water storage facilities required for gravity delivery of a dependable supply of 70 mgd through a pipeline to be constructed by the consumers of the water.

The costs of delivery and treatment facilities for both reservoir projects will be borne by the consumers, in accordance with the enabling legislation.

Spruce Run–Round Valley Program

After approval of the 1958 water supply law, steps were taken immediately for the adoption of a program for the earliest completion of the two authorized reservoir projects and for the recruitment of personnel for a temporary bureau of design and construction. Consulting engineers were interviewed in December 1958 relative to experience and qualifications for the design of rolled earth-fill dams. In order to supplement information contained in a special report, a contract was awarded early in January 1959 for the continuation of the core-boring program initiated at the Spruce Run Dam site in 1958. Contracts for the preparation of aerial topographic maps and other surveys required for the design of the dams and road relocation were also awarded. The contracted work has been completed.

In February 1959, headquarters office for the temporary bureau was established at Trenton, N.J. Shortly thereafter, field offices were opened at the Spruce Run Reservoir site, under the direction of the division engineers in charge of construction of these reservoirs. In May 1959, contracts were awarded for engineering services in connection with the design of the Spruce Run Dam and appurtenant structures, and for the Round Valley dams, dike, and appurtenant structures. Both contracts provided for completion of designs and specifications by the end of 1959.

The core-boring program contracted in January 1959 for the Spruce Run Dam site was continued under supplemental contracts and completed in December 1959. By October 1959, 193 holes had been completed and pressure tested in the Spruce Run area, involving a total length of 21,590 lin ft. The majority of these holes will be used for grouting during subsurface construction.

The core-boring program in the Spruce Run area was supplemented in October 1959 by a contract for experimental grouting to provide data for the preparation of specifications and cost estimates for the construction of a satisfactory watertight cutoff at the dam and dike and along the ridge of the reservoir adjacent to Route 69.

This program was conducted in accordance with specifications prepared by the consulting engineers, and was completed in November 1959.

For the Round Valley dams and dike sites, 80 holes have been completed and pressure tested by the consulting engineers, involving a total length of 5,710 lin ft. This core-boring program was supplemented by an experimental grouting program.

In June 1959, a generalized geologic investigation program was begun by the Bureau of Geology and Topography of the Division of Planning and Development of the State Department of Conservation and Economic Development to assist the Division of Water Policy and Supply in evaluating the subsurface conditions in both the Spruce Run and Round Valley areas. A report on these conditions is being prepared.

In April 1959, a contract was made with Rutgers University, New Brunswick, N.J., for electronic-computer services for the analysis of the operation of the Spruce Run–Round Valley reservoir system under stream flow conditions experienced during May 1, 1930–Dec. 31, 1957. This analysis and other studies completed by the newly created water development section of the division bureau of water resources provide the basic data required for the allocation of project costs, the establishment of equitable rates for water sale, and the operation of the reservoir system on completion of construction. They also provide valuable, long-term data for evaluation of the economics involved in the design of pumping stations for diversion of water to fill the Round Valley Reservoir and for booster pumping for delivery of the water to certain areas of demand.

In October 1959, a contract was awarded for engineering services for the preparation of contract drawings and specifications for the Round Valley relocated road, which must be completed before construction can be started on either the north or south dams. A similar contract is being executed for the design of the Spruce Run Bridge and two other stream crossings needed for relocating roads to Spruce Run Lake Reservoir.

For the Round Valley Reservoir, the land acquisition program was completed, except for one parcel still under litigation, prior to the referendum approval in November 1958. Negotiations are now being conducted to acquire the right of way required for the relocated road. The land acquisition program for the Spruce Run Lake Reservoir has been conducted by the Department of Conservation and Economic Development, in accordance with procedures established by the commissioner of the department for the acquisition of the Round Valley property; 95 per cent of the needed lands have already been acquired.

Water Sale Program

The Division of Water Policy and Supply initiated conferences in December 1958 with the North Jersey District Water Supply Commission, Elizabethtown Water Co. Cons., and the city of Newark to investigate the interest in the sale of water to be developed by the two authorized projects and the methods for determination of the water charges to be made for each project. In accordance with these negotiations, the district commission proceeded to obtain resolutions from eleven municipalities and one county expressing interest in a total of 62.175 mgd of

Round Valley water and authorizing that commission to: (1) investigate the cost of the required delivery and treatment facilities, (2) represent the municipalities in an application to the US Housing and Home Finance Agency for a federal loan to complete preliminary studies of these facilities, and (3) represent the municipalities in applying to the State Water Policy and Supply Council for allocations of water.

Similar conferences were held with representatives of the Elizabethtown Water Co. Cons. with reference to the sale of Spruce Run water. It is anticipated that the questions involving the allocation cost and demand charges will be resolved shortly.

Ground Water Investigation

The statewide program is limited by enabling legislation to an annual expenditure of $125,000, of which at least $100,000 will be allocated for a cooperative investigation with the Ground Water Branch of the Water Resources Division of USGS, on an equal cost-sharing basis. An allocation will also be made to the State Bureau of Geology for the review, tabulation, and compilation of well records and other geologic data pertinent to these studies. The program was initiated in January 1959 by a special allocation of $50,000 for the construction of certain test and observation wells.

During 1959, comprehensive studies were conducted in Monmouth, Salem, and Mercer counties, in the Pine Barren area, the Sayreville area of Middlesex County, the Phillipsburg area of Warren County, and the Wharton Tract for a report by the end of the current fiscal year (Jun. 30, 1960) on Mercer County. In Salem County, several new observation wells were established and pumped, and a new 718-ft well was drilled near Woodstown and tested at various levels. Two new observation wells have also been constructed to the 800-ft sands in the Atlantic City area to replace existing observation wells from which data are considered to be questionable.

A preliminary report setting forth the significant results of the Cape May County special study investigation has already been published.[1] Three larger reports summarizing the results of this investigation and a report on selected wells in Monmouth County are scheduled for publication.

In the Wharton Tract, collection of basic water data was continued, and five new observation wells were installed. A large-capacity test well is under construction to evaluate the Cohansey sand aquifer in this tract and to test the feasibility of induced river recharge.

The Sayreville study was undertaken to evaluate the extent of salt water encroachment into the Farrington sands—which endangers industrial and public supplies—to consider remedial measures therefor, and to provide the technical data for the design of a tidal dam on South River for the protection and recharge of the Old Bridge sands. A report is scheduled for completion in the latter part of the fiscal year ending Jun. 30, 1961, at which time consideration will be given to the execution of an engineering contract for the design of the tidal dam and for comparative economic studies of the dam and other remedial measures.

For the current fiscal year, priority of effort on new programs is to be given to Morris County, with particular reference to the old Lake Passaic area which is dependent on ground

water sources. Studies will also be initiated in the latter part of the year in Camden and Burlington counties to supplement the information already published.

Pensauken Investigation

The Pensauken investigation was initiated in May 1959 by the awarding of a contract to a consulting ground water geologist for the preparation of a preliminary report concerning the available factual geologic and other data relative to the test program, the additional factual data that should be developed to insure an adequate test, the size and design of the pilot installation to be constructed, and the type of test to be conducted. A generalized geologic survey was also undertaken by the State Bureau of Geology. A report by the consulting geologist has been completed and reviewed; a report on the survey conducted by the Bureau of Geology is being prepared.

Surface Water Studies

Studies of the Raritan-Millstone Basin have been initiated by contract for the preparation of aerial topographic maps of the North Branch Reservoir site on the North Branch Raritan River and of the Rocky Hill Reservoir site on a lower tributary of the Millstone River. Preliminary studies have been started by the Bureau of Water Resources of the division to develop basic hydrologic data. Priority of effort is to be given to the preparation of a report on the desirability and practicability of the North Branch Reservoir site.

Surface water studies pertaining to the rest of the state have been deferred until the completion of the comprehensive survey of the water resources and water needs of the Delaware River Basin. This survey, to be reported in May 1960, is being conducted by the US Army Corps of Engineers and other federal agencies under a directive of Congress.

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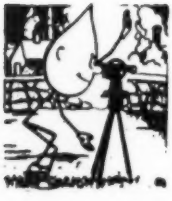

Public Health Aspects of Water Reuse for Potable Supply

Bernard B. Berger

A paper presented on Oct. 20, 1959, at the joint meeting of the Alabama-Mississippi and Southwest sections, New Orleans, La., by Bernard B. Berger, Chief, Water Supply & Water Pollution Research, Div. of Water Supply & Pollution Control, Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.

THE use of a ton of clean water to carry away a few pounds of waste solids appears to be a foolish expenditure of a valuable resource, and it poses an interesting question: whether it is feasible to treat sewage so that the recoverable water may serve all municipal purposes, including water for drinking.

Recent Reuse Experience

The use of treated municipal sewage for all municipal purposes is unusual, but the concept is not completely bizarre. The experience of Chanute, Kan., is a striking example.[1] Sewage was recycled through the city 8–15 times during a period of 5 months—October 1956 to February 1957. Sewage was similarly reused for all municipal purposes by Lyndon, Kan., in the fall of 1956 when the normal water source dried up.[2] It is interesting to note that in both instances the municipality itself made the decision to reuse its sewage as the best possible solution to the water supply problem. In neither city was prior approval sought from public health authorities. Ottumwa, Iowa, in 1940, faced a particularly difficult reuse problem when approximately 60 per cent of the flow in the Des Moines River, the supply source, consisted of septic raw sewage discharged by the city of Des Moines.[3] In all these instances, the finished water met bacteriologic requirements of the USPHS Drinking Water Standards.[4] At Ottumwa, however, free residual chlorination at 112 ppm chlorine dosage produced a peculiar separation of solids resembling blood clotting. The Chanute situation was unique in that it offered a good opportunity to the state and to USPHS for monitoring the quality of water during the period of recycling.

Something short of direct recycling is the rule in hundreds of United States cities. Most municipalities, drawing their water from the great inland streams, are, in fact, using the diluted sewage effluents of upstream cities. It is interesting to observe that although the presence of such pollution is generally known, consumer acceptance of the water does not appear to be reduced appreciably. Obviously, dilution and elapsed time dissipate aesthetic objections. Presumably, this would not be so in direct recycling.

Water reuse can be expected to increase for one simple reason: given a growing population and industry and a fixed water supply, the reuse factor must inevitably become greater. Rec-

ognition of the future need for water reuse is forcing public agencies to consider new concepts of water quality management. It may even become feasible to practice complete recovery of the water component of municipal sewage—the pure water that makes up 99.9 per cent of sewage (by weight). This concept could place another Chanute situation in a healthful, aesthetically acceptable, and economically favorable light.

Public Health Considerations

It is assumed by many that waters recovered from sewage may be made completely safe by application of modern waste and water treatment procedures. Even after approximately a dozen cycles, the Chanute water supply met the bacteriologic requirements of the USPHS Drinking Water Standards. The problem, it is believed, is to improve consumer acceptance of the finished water. There are, however, a number of physical, microbiologic, and chemical factors pertinent to the question of water reuse and public health. It is assumed here that sewage treatment includes the activated-sludge process and chlorination, and that these are to be followed by conventional water treatment.

Physical Quality

The effluent of a properly performing activated-sludge sewage treatment plant compares well in appearance with most surface water supplies. Under normal operating conditions, it contains practically no settleable material, and its concentration of suspended solids may be considerably less than that of many streams. Turbidity is low and occasionally such effluent has even been described as "sparkling." Being well stabilized, the effluent has an insignificant odor. Its color is innocuous, unless large quantities of colored industrial wastes are discharged into the city sewers. If the origin of the used water were not disclosed, few would object to its use as a source of public water supply.

The appearance of activated-sludge effluent is not always so favorable, however. Biologic systems are unstable and disturbances produced by slight changes in environmental conditions may result in marked deterioration of the effluent. Such deterioration is often characterized by appearance of masses of poorly settling biological floc in the plant discharge. The condition triggering this damaging effect may be too subtle and too sudden to identify and control. Any immediate recycling of such water would probably be out of the question.

The appearance of froth often associated with household detergents is a factor of unknown proportions. In a recent survey, 97 of 104 plants employing activated sludge reported occasional difficulty.[5] Research currently being supported by the American Association of Soap and Glycerine Producers may solve this problem.

Bacterial Pathogens

A recent review of information on reduction of microorganisms by sewage treatment describes the present unsatisfactory state of knowledge concerning the fate of pathogens during sewage treatment and emphasizes the need for improved methods for their demonstration and enumeration in contaminated waters.[6] Satisfactory information is available only for coliform organisms, the indicators for human fecal discharges. As differences in resistance to environmental factors are

probably small among vegetative bacteria, it is normally assumed that the fate of coliform organisms reasonably reflects that of pathogenic bacteria. The validity of using coliform organisms to determine the fate of microorganisms other than vegetative bacteria is debatable. This question is especially pertinent to the 1955–56 waterborne outbreak of infectious hepatitis in Delhi, India,[7] where the treated water was reportedly free from coliform organisms during the period of virus contamination (although the bacteriologic data were very scanty).*

It has been reported that concentrations of bacterial pathogens in sewage are reduced 90–99 per cent by activated-sludge treatment.† This reduction could still leave significant concentrations in the effluent. For example, with a 99 per cent reduction in coliform organisms, the residual concentration would approach 1,000,000 per 100 ml. This concentration, high as it is, is hardly discernible to the unaided eye, and should not be associated with marked turbidity.[8] Chlorination of the plant effluent providing a measurable orthotolidine chlorine residual after 15 min of contact would reduce the concentration of coliform bacteria in the plant effluent again by 99 per cent.†

It has been established that a well operated conventional water treatment plant can reduce very heavy loadings of coliform bacteria to practically zero.[9] It is generally believed that it may do the same for bacterial pathogens. Chemical coagulation plays a role in achieving this desirable result by removing approximately 95 per cent of the coliform organisms. Both pre- and postchlorination, however, are of critical importance. Rapid sand filtration, the most costly component of the modern treatment plant, was not highly efficient in removing bacteria in recent tests at the Taft Center, particularly immediately after backwashing.

Fungal Pathogens

The aeration tank of an activated-sludge system supports a large and active mold population. Many species actually compete with bacteria for the nutriment in sewage.[10] Hardiness of molds is attested by their ubiquity and persistence in surface waters. Attempts to utilize molds as indicators of pollution failed because of the ability of molds to survive under changing water quality conditions.[11]

Pathogenic species of fungi have been been encountered in sewage treatment plants and polluted streams.[12] One study [13] indicates that the resistance of fungal spores to chlorination exceeds that of bacteria. As far as is known, none has been isolated from drinking water sources. It cannot be said, however, that a careful and thorough survey has ever been made. Public health needs may not justify this effort under present water use conditions, but with intensive reuse of contaminated waters, approaching the direct recycling of sewage, more information should be obtained on the prevalence of fungi in waters and on

* Not only were the bacteriologic data "scanty," but, according to Wolman,[7] who made strenuous efforts to obtain information, they were either nonexistent or, at any rate, had not been released 2 years after the event. Without facts, it is difficult to see why the coliform test should be indicated any more than the water treatment procedures used. From the reports of Wolman and Dennis it appears that "apathetic control, lack of hour-to-hour alertness, administrative jealousy and competition, and failure to adjust promptly to catastrophic conditions," rather than the techniques involved, were at fault.—Ed.

† See Kabler [6] for references.

the resistance of spores and other developmental stages to water treatment processes.

Enteric Viruses

Interest in enteric viruses in water has risen sharply in the last few years as a result of the growing number of virus types, 70 at the last count, recovered from human feces and sewage. Interest has also been aroused by the waterborne outbreak of infectious hepatitis at Delhi. Present knowledge on enteric viruses in water has been reviewed by Clarke and Chang of the Taft Center.[14] Their study of reports on virusborne outbreaks indicates that infectious hepatitis is a waterborne virus disease. Only one outbreak of poliomyelitis, however, is now suspected of having been caused by a contamined municipal water supply in the United States.* This occurred as a result of back siphonage of sewage into the distribution system. On the basis of present information, epidemiologists do not consider the water route to be an important means of transmitting other viruses. This may possibly be a result of the general lack of information on the clinical illness that many of these viruses produce. It is possible also that the illnesses produced are so mild that they are not reported to health authorities.

In evaluating the ability of water treatment processes to remove viruses, Clarke and Chang concluded that viruses persisted under water storage conditions; were reduced in concentration by 95–99 per cent when subjected to flocculation with alum or ferric salt, and were inactivated by free chlorine but not by combined chlorine.

Little information is available in the literature on the ability of sewage treatment processes to remove viruses. Clarke is currently engaged in such studies utilizing sewage containing Coxsackie virus. His findings indicate that sedimentation is not effective in reducing virus concentrations but that removal of approximately 95 per cent occurs in the activated-sludge process. The virus is presumably not destroyed but probably most of it is adsorbed on the floc.

Three factors should be considered in determining the virus hazard in a water use situation involving direct recirculation of sewage.

1. As long as the activated-sludge treatment plant is operating properly, the great bulk of viruses will be removed from the plant effluent. It has already been noted, however, that when activated-sludge systems are upset, part of the floc escapes with the effluent. Undoubtedly at such times heavy virus loadings would be received at the water treatment plant.

2. The extent to which substances in the sewage plant effluent would interfere with virus removal by coagulation at the water treatment plant is not known. It is probable that removal efficiency would be lowered.

3. A free chlorine residual would be difficult to obtain because of the nitrogenous substances in the sewage plant effluent. A free residual was not attained at Chanute.

One may justifiably conclude that the problem of viruses in water supplies derived from highly contaminated sources has not been solved and that flaws exist in present protection barriers.

Parasitic Protozoa

The single report cited by Kabler [6] on the fate of *Endameba* cysts in an activated-sludge system indicated no

* See Clarke and Chang [14] for reference.

reduction in the concentration of this parasite. Parasitic protozoa were absent in the treated sewage at Chanute. *Endameba* cysts were recovered from only one of ten samples. None was recovered from the raw water. In all of ten samples of raw water, however, live cysts of free-living (nonpathogenic) amebas were detected. In every instance but one, the cysts were also detected in finished water. As these were of about the same size and presumably had comparable resistance to active chlorine as the *Endameba* cysts, it may be assumed that had the latter been present in the raw water they would also have appeared in the finished water.

Penetration of the water treatment plant by cysts 10 μ or more in diameter is surprising. One would expect that the treatment processes practiced at Chanute would have effectively removed these organisms. Their failure may reflect, in part, the unusual stress under which the plant was being operated. Further evidence of unsatisfactory filtration was the large amount of algae and debris (approaching 20 μ in diameter) in the treated water. It would seem desirable to review the effectiveness of water treatment in removing cysts before these processes are subjected to the kind of challenge faced in Chanute.

Parasitic Worms

Considerable interest in worm infestation of water distribution systems will probably be stimulated by Chang's recent report that, in fourteen of fifteen cities using streams as water sources, free-living nematodes were found in the finished as well as in the raw water.[15] None of these worms was a human parasite. Their presence shows, however, that conventional water treatment may not be reliable protection against the ingress of such organisms. Chang found further that nematodes isolated from tap water from two of the cities examined could ingest *Salmonella* and *Shigella* bacteria and enteric viruses and carry them through a high free-chlorine barrier.[16] The likelihood of the occurrence, however, is considered to be very remote. Chang's observations, when added to observations of others on distribution system infestations with copepods,[17] Nais worms,[18] and water lice,[19] suggest the timeliness of research on the biota of distribution systems.

Reports on removal of parasitic ova by the activated-sludge process are conflicting. Kabler's review of the literature on this subject reports findings ranging from no reduction to complete removal.[6] The aeration tank appears to be an excellent hatchery for *Schistosoma japonicum* ova with miracidia appearing in the effluent in large numbers. These will not produce human infection, however, without passage through appropriate water snails. Ova appear to be highly resistant to chlorination. The miracidia are much more vulnerable.

This apparent vulnerability of water treatment systems to worm passage suggests an additional aspect to the extraordinary load water treatment must carry in reuse of treated sewage for municipal water supply purposes. Although no parasitic worms are known to be normally transmitted from human to human through water without an intermediate host or a soil development phase, the possibility of a hazard should be assumed to exist.

Infectious Disease

One must conclude that the extreme challenge presented by water contain-

ing a high percentage of fresh sewage effluent might overtax the protective capacity of the modern water treatment processes. Outbreaks of infections resulting from penetration of the treatment plant by disease-producing organisms are a potential danger.

Undesirable Chemicals

The growing national concern with persistent, possibly injurious, synthetic organic chemicals in the environment has so far involved domestic sewage only in respect to its content of alkyl benzene sulfonate (ABS), the essential ingredient of household detergents. This compound has been suspect mainly because it can be recovered in measurable concentrations in treated water supplies. Sewage may contain other and perhaps more important synthetic organic chemicals, which, unlike ABS, give no physical or chemical indication of their presence and remain undetected. The ever increasing number and variety of these organic chemicals on the market undoubtedly are reflected in a changing character of domestic sewage. Resolution of the complex soluble organic chemicals of sewage into specific compounds has not hitherto been considered necessary or feasible.

Municipal waste is more complex than domestic sewage because of the waste contribution by industrial and commercial establishments connected to the municipal sewer. Public officials usually are alert to the damages that may be produced by industrial discharges. Before accepting industrial wastes they require evidence that the wastes are not damaging to sanitary structures or toxic to the biological systems on which waste treatment depends. Few, if any, municipal sewerage authorities require assurances from industry that the wastes will not harm downstream water supplies, however.

Inorganic Chemicals

Analytical procedures are available for most inorganic components of sewage. A well equipped water utility laboratory should be able to identify and measure most significant inorganic compounds that may be present. Information on increments in concentrations of such compounds resulting from water use has been recorded, or may be readily obtained in the laboratory. The data obtained in the Chanute studies were of particular interest because of the multiple recycles used. With a few exceptions, increases in inorganic compounds were of the same general order as those reported by the state of California.[20] The exceptions were explained on the basis of chemical and biologic action occurring in the large shallow impoundment used at Chanute. For example, the small increment of sulfates at Chanute could have resulted from anaerobic breakdown of this compound in the pond.

Organic Compounds

The identification and measurement of specific organic compounds in a sewage plant effluent are more demanding jobs. Actually it is doubtful that a complete analysis of this type is even possible at present. *Standard Methods* does not include procedures for such analyses. Earlier considerations of waste treatment and water use did not require such information.

The Taft Center encountered this problem in the fall of 1958, when it was asked to make a special analysis of the activated-sludge effluent of a large Midwestern city. Employing the most sensitive techniques available at the laboratory, it was attempted to determine, by broad chemical groupings,

the concentration of soluble organic compounds in this fraction of the plant effluent. In this study, the total soluble organic content was assumed to be equal to volatile solids, as measured by loss on ignition corrected for carbon dioxide. The groupings were the following: fats and oils, ether solubles other than fats and oils, proteinaceous materials, nonproteinaceous nitrogenous materials, carbohydrates, and ABS. Only 25 per cent of the soluble organics could be accounted for, and then only with a low order of specificity.

This unsatisfactory result has made necessary a more intensive study to identify and measure the stable organic content in the effluent of a secondary sewage treatment plant. At the very outset of the study it was found that the standard procedures for estimating organic content, loss on ignition, and chemical oxygen demand were not reliable quantitative yardsticks. Escape of inorganic gases and bound water introduced errors in the loss-on-ignition determination. Organic structures, including pyridine and certain amino acids, were not measurable by chemical oxygen demand. Chlorine demand, commonly used in water utility laboratories as a measure of organic strength, was not included, because, at best, chlorine oxidizes only a minor fraction of organic chemicals in sewage.

It is possible that new soluble deleterious chemicals that cannot be handled by conventional methods of water treatment may be found in a sewage plant effluent used as a water source. If they are, improved methods of water treatment will have to be developed to remove them.

Chemicals and Health

The Taft Center does not consider these studies an excursion into areas of merely academic curiosity. The widespread interest in recovery of the valuable water component of municipal sewage and the trend toward more intensive water reuse require an intelligent appraisal of the health significance of all sewage components including those in body discharges and the synthetic organics of industrial origin.

Interest in the aspects of chemicals in the environment is growing. The following excerpt from the final report of the APHA Water Supply Committee is pertinent [21]:

> The fact that records do not reveal any human illness involving synthetic organic substances in a public water supply does not give any assurance for the future, since it must be assumed that there is a limit to human tolerance to those materials, even in dilute concentration. Perhaps this limit has already been reached in certain areas with respect to certain substances, without symptoms having been recognized. A careful comparison of health statistics in selected areas might reveal signs that have been overlooked.

Conclusion

Modern sewage treatment processes are designed to produce an effluent that will be easily assimilated by the receiving body of water; they are not intended to produce a water suitable as a source of municipal water supply. Modern water treatment processes are designed to treat a moderately contaminated and turbid water so that it may be safely drunk; they are not intended to treat raw water approaching sewage plant effluents in quality. A combination of current sewage and water treatment processes should, therefore, not be considered adequate to convert sewage to safe drinking water. Total recovery of the pure water in municipal sewage will require a much better understanding of the microbial and chemical challenges involved. Ex-

panded research on advanced water-cleansing processes is necessary.

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Monitoring the Ohio River for Synthetic-Detergent Content

Paul J. Weaver and Francis J. Coughlin

A contribution to the Journal by Paul J. Weaver, Head, San. Eng. Research Services, and Francis J. Coughlin, Assoc. Director, both of the Product Development Div., Ivorydale Tech. Center, Procter & Gamble Co., Cincinnati, Ohio.

THE average concentration of surface-active agents in the Ohio River at Cincinnati, based on weekly analyses with the methylene blue procedure over a 5-year period, has been 0.16 ppm, measured as "apparent ABS." (ABS is the abbreviation for alkyl benzene sulfonate, the principal surfactant in household synthetic detergents.) This is a small concentration, particularly when compared with the 1-ppm concentration reported as the approximate value at which light frothing may first appear. During this period there was no increase or build-up of the apparent ABS content, and no water treatment problems that might be associated with detergents were reported.

These results are based on a monitoring program started by Procter & Gamble Co., Cincinnati, Ohio, early in 1954. The program was established as a part of the work of the Detergent Subcommittee of the Chemical Industry Committee, advisory to the Ohio River Valley Water Sanitation Commission (Orsanco). This subcommittee was formed at the suggestion of Edward J. Cleary, executive director and chief engineer of Orsanco, to aid in the appraisal of questions concerning the possible effects of synthetic detergents in water and sewage.

Probably the most significant of the various steps taken by the Detergent Subcommittee was that of enlisting the support of the Association of American Soap & Glycerine Producers, New York, N.Y., in a major research effort directed toward answering the questions about the effects of synthetic detergents. The association's research has been reported at its 1956–1959 annual conventions by Coughlin and Moss.[1–4] The monitoring program on the Ohio River, however, is not so well known.

Monitoring Program

When the Detergent Subcommittee was organized in 1954, the Procter & Gamble representative, being the member of the subcommittee located nearest to the Ohio River, volunteered to set up a regular weekly program to monitor ABS. Since that time, and during the period covered by this article, only a portion of the domestic sewage of Cincinnati has been treated, so that the large bulk of the city sewage has been introduced directly into the Ohio River. This condition, of course, is now being alleviated as treatment plants are completed and put into operation. During the report period, however, this kind of sewage disposal provided a good indication of the ABS

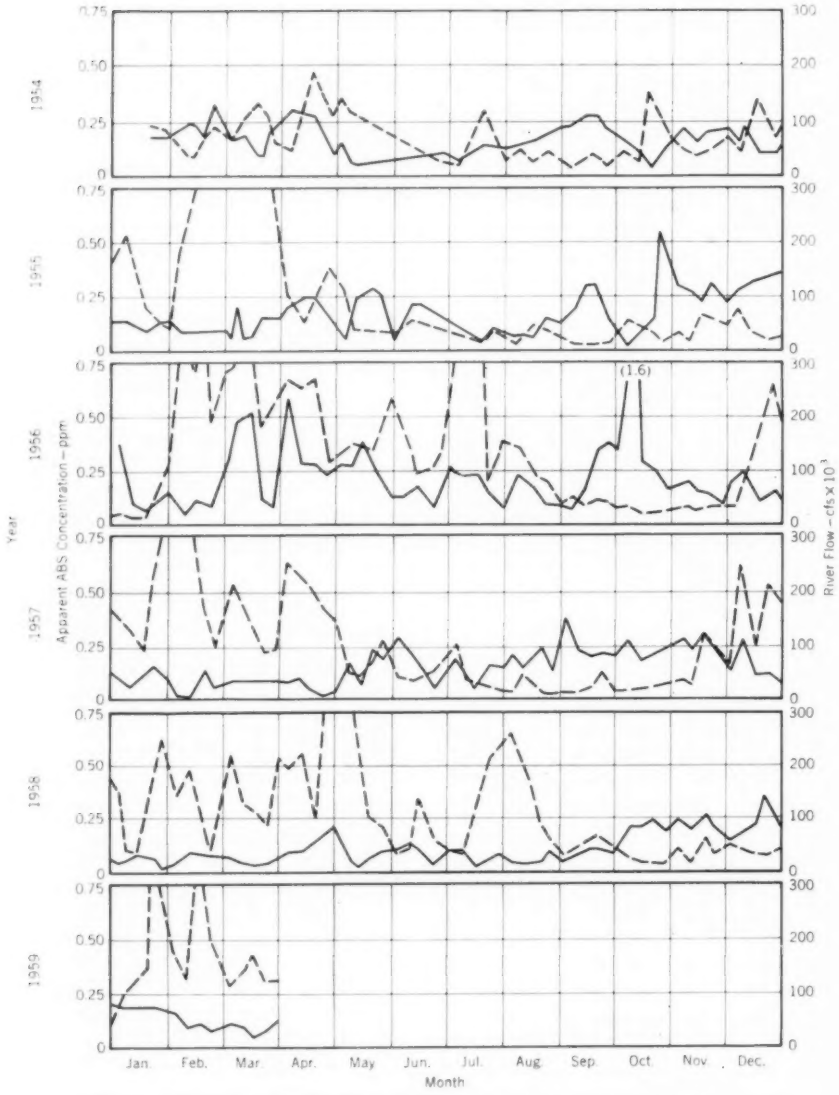

Fig. 1. Apparent ABS Concentrations With Relation to River Flow in Ohio River at Cincinnati

The solid curves represent the ABS concentrations; the dashed curves, river flow. The rough relationship between increasing river flow and decreasing apparent ABS is inadequate for predicting the ABS level from river flow at any specific time.

concentrations that might be expected in a river such as the Ohio when essentially all the wastes, including synthetic detergents that the housewife pours down the drain, flow directly into the river without any biologic treatment, except that which might take place in the sewer lines themselves.

A sampling point was selected just below Cincinnati at Anderson Ferry, Ohio, where a small river ferry carries automobile traffic between Ohio and Kentucky. This ferry makes it easy to take samples at different points across the entire river. At this site, close to the point where ABS is introduced into the river, the highest concentration is expected, because no more than the normal diluting effect of the river takes place, and there is little time for ABS die-away.

Samples were obtained once a week, with either three or four samples taken on each weekly visit. These were obtained by lowering a sampler into the river from the ferry to a depth of 2 ft. The samples were immediately transferred to quart-sized mason jars, and 0.5 per cent by volume of chloroform was added to prevent bacterial degradation of the ABS. All equipment was carefully cleaned with acid prior to use, so that no residual ABS was present on the glassware. The individual samples were then sent to Procter & Gamble's service laboratory for analysis and averaged to give a weekly result.

TABLE 1

*ABS Concentrations in Ohio River Samples**

Classification	Apparent ABS† *ppm*
Median	0.12
Average	0.16
Weekly high	0.59
Weekly low	0.01

* Base: 832 individual samples, collected 1 day per week during Jan. 21, 1954–Mar. 31, 1959.
† As determined by the methylene blue procedure.

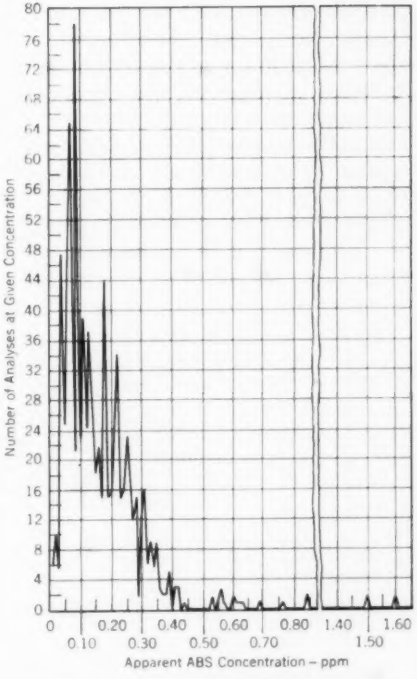

Fig. 2. Frequency Distribution of Apparent ABS

The frequency distribution is for data shown in Fig. 1—832 individual samples collected during Jan. 21, 1954–Mar. 31, 1959.

It should be noted that the analytic method used in this program was, from the beginning, the methylene blue procedure, as modified by Degens and associates [5] from the basic method of Jones.[6] This is the same method published by AWWA Task Group 2662 P —Analytical Methods for Synthetic Detergents.[7] Despite the fact that this method is known to be subject to interferences from naturally occurring materials—which will analyze as ABS when actually they are not—and despite the fact that these interferences are present in practically all surface waters,

the method was used from the start for two reasons. First, when the program was initiated, it was the only method available. Second, it was eventually ascertained that even the sum of the true ABS concentration and the concentration of interfering materials recheck, by the precise infrared method, any individual samples with relatively high indicated ABS levels. In addition, eleven samples were routinely analyzed by the infrared method to obtain background information on the degree that materials in the Ohio River

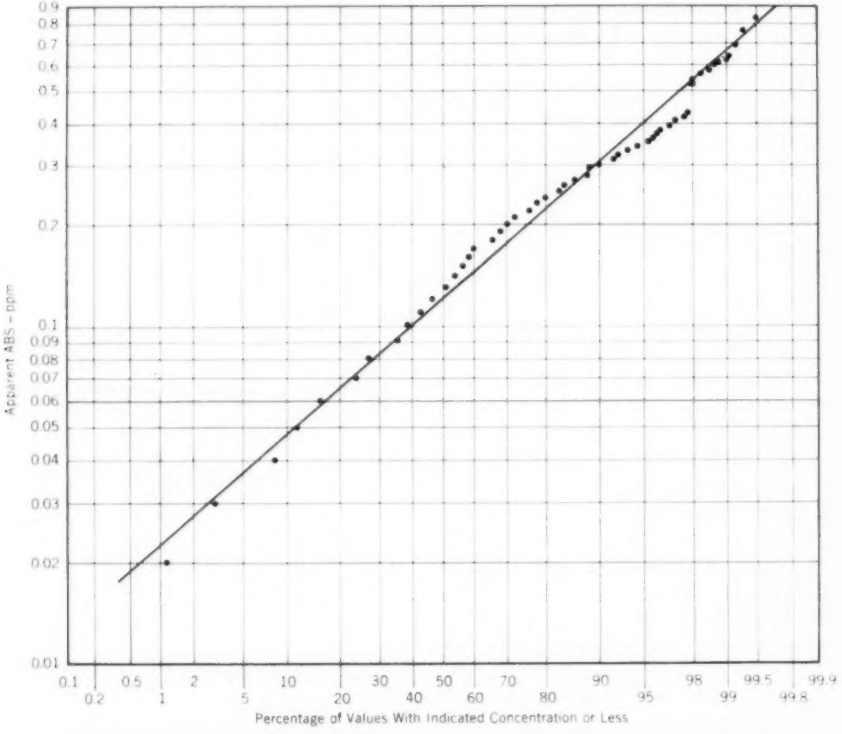

Fig. 3. Apparent ABS Data Plotted on Logarithmic Probability Scale

From this type of graph, the percentage of values at or less than any given concentration can be determined, and an indication readily obtained of how often the greater concentrations may be expected.

sulted in such a low apparent ABS level that it was unnecessary to determine the true ABS level by the lengthy infrared referee procedure developed later by the Analytical Subcommittee of the Soap Association.[8] At the same time, preparations were made to interfere with the methylene blue procedure.

Monitoring Results

Table 1 shows the overall median, overall average, weekly high, and weekly low results obtained from the

analysis for apparent ABS of 832 individual samples taken during January 1954–March 1959. The median figure, 0.12 ppm apparent ABS, is probably a more realistic value than the average figure of 0.16 ppm for the typical apparent ABS levels to be expected in the Ohio River. Of all these samples, only one week's series analyzed at a value greater than the weekly high that is shown in Table 1. This greater value of 1.6 ppm is not included in Table 1 because it clearly should be discarded, based on statistical considerations.

With regard to the series of samples analyzed at 1.6 ppm, it should be noted that when the samples were taken there was no evidence of frothing or other unusual effect. As soon as the apparent ABS content was available, an additional sample was obtained so that the infrared procedure could establish how much of the 1.6 ppm was true ABS and how much interference. Unfortunately for this purpose, when the check sample was taken the river was back to its normal low levels.

Figure 1 shows these data by month and year. For comparative purposes, data are also included for the river flow on the comparable sampling date. There seemed to be a rough correlation between increasing river flow and decreasing apparent ABS content, and a statistical analysis confirmed that a general inverse relationship exists. This relationship, however, is not adequate for predicting the ABS level from river flow at any specific time, as can be seen by the extreme variability of the plotted data.

Figure 2 shows the individual data plotted as a frequency curve. The large bulk of results were in the range of 0.04–0.22 ppm apparent ABS. The limits of this range bracket the median and average values.

The same overall data plotted on a logarithmic probability scale are shown in Fig. 3. From this type of graph, the percentage of values found at or below any given concentration can be determined, and an indication readily obtained of how often the greater concentrations may be expected. For example, the figure shows that in the Ohio River below Cincinnati, 90 per cent of the time the concentrations of apparent ABS, as determined by the methylene blue procedure, were 0.32 ppm or less; 95 per cent of the time, the concentrations were no greater than 0.41 ppm. If there are no major changes in the use or formulations of detergents, it becomes clear that only rarely can the larger apparent ABS concentrations be expected in the future.

TABLE 2

Comparison of Results of the Referee Infrared Procedure and Methylene Blue Procedure

Date Sampled *1958**	Procedure	
	Infrared	Methylene Blue
	ABS Concentration—*ppm*	
Feb 11	0.02	0.09
Feb. 25	0.12	0.18
Mar. 4	0.07	0.07
Mar. 10	0.02	0.05
Mar. 24	0.03	0.06
Apr. 14	0.02	0.18
Apr. 29	0.03	0.22
May 13	0.01	0.04
May 27	0.02	0.10
Sep. 9	0.03	0.21
Feb. 10	0.01	0.10
Average	0.04	0.12

* Except for the last date, Feb. 10, 1959.

Table 2 compares the results obtained from the eleven samples analyzed by the referee infrared procedure and the methylene blue procedure. Al-

though these randomly chosen samples showed small ABS concentrations with both methods, the fact that positive interferences were present in most instances is clear. Predominating negative interferences were absent in all instances.

Summary

The monitoring program, which has been in progress over the past 5 years, shows that the apparent ABS concentrations found in the Ohio River just below Cincinnati are small and are not increasing. The true ABS concentrations must be even less than the average of 0.16 ppm found. During this sampling period there has been no problem with the treatment of water for community purposes which in any way could be attributed to synthetic detergents. The duration of the monitoring period and the general observation of conditions on the Ohio appear to be adequate to give a reliable picture. The results of the program indicate that problems due to detergents should not be expected in the future.

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Survey of Free-Living Nematodes and Amebas in Municipal Supplies

Shih L. Chang, Richard L. Woodward, and Paul W. Kabler

A contribution to the Journal by Shih L. Chang, Medical Director; Richard L. Woodward, Chief, Eng. Sec.; and Paul W. Kabler, Chief, Microbiology, all of the Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.

THE persistent occurrence of free-living nematodes in a city water supply was reported in May 1959 [1] and has led to the speculation that the presence of nematodes in municipal water supplies may be more common than has been generally realized. A survey of a representative group of large city water supplies in the United States has, therefore, been conducted. A search for viable cysts of free-living amebas in the finished waters has also been made.

Survey Methods

Arrangements for collection and shipment of one raw- and one finished-water sample were made either directly with the water utility, water commissioners, state health departments, or through the regional offices of USPHS. All samples were collected in 2½-liter plastic bottles and shipped without refrigeration or preservatives.

Upon receipt of the samples, the entire volume of each sample was filtered through a SS type (3 μ pore size) membrane filter, and the concentrate was examined in the manner described in the previous article.[1] When nematodes were observed under the microscope, the whole concentrate was pipeted into a centrifuge tube and centrifuged at 500 rpm for 5 min. The sediment thus obtained was used in preparing stained specimens for identification. When a concentrate showed a worm population of more than 10 per gallon, half of the sediment was used in identification and the other half in cultivation by the technique described in another report.[2]

When a raw-water sample had a high turbidity and, consequently, a poor filtrability, 500–1,000 ml was filtered through 2–4 membranes. The concentrate was washed from each membrane and examined separately to avoid the possibility of overlooking nematodes hidden by particulate matter.

When amebic cysts were shown to be present in a finished-water sample, 2–3 drops of the sediment, after centrifuging, were placed on a buffered sucrose nitrate agar plate preseeded with *Proteus mirabilis* for viability and identification.[3, 4]

Results

During the 11-month period beginning in December 1958, 22 city water supplies had been examined. Of this total, fifteen used river waters as their sources of supply, six used lake or impounded waters, and one used impounded river water. The occurrence

of nematodes and amebas in these water supplies is shown in Table 1, and the distributions of nematode genera and amebic genera and species are shown in Table 2.

ing nematodes showed populations of more than 10 worms per gallon in the raw water, and two of them had 30 or more worms per gallon. Ten of the finished-water samples showed a

TABLE 1

Occurrence of Free-Living Nematodes and Amebas in Municipal Water Supplies

State	Raw-Water* Source Type	Type of Treatment†	Raw Water			Finished Water			Live Amebic Cysts in Finished Water‡
			Alive	Dead	Total	Alive	Dead	Total	
			Estimated No. of Worms per Gallon						
Georgia	R	RD	5	0	5	2	0	2	–
California	R	RD	2	2	4	2	0	2	–
Washington	R	RD	12	0	12	2	0	2	–
Pennsylvania	R	SD	3	9	12	0	3	3	–
Michigan	R	RD	0	0	0	0	0	0	–
Texas	R	RD	3	6	9	0	5	5	+
Massachusetts	R	RD	5	3	8	3	5	8	+
Illinois	R	RD	3	5	8	0	3	3	–
Louisiana	R	RLD	2	0	2	0	2	2	–
Kansas	R	RLD	10	2	12	9	3	12	+
New York	R	RD	5	0	5	2	0	2	+
West Virginia	R	RD	20	10	30	3	5	8	+
Maryland	R	RD	12	3	15	3	0	3	+
Texas	R	RLD	28	10	38	29	9	38	+
Tennessee	R	RD	12	3	15	3	5	8	+
Colorado	R§	RD	3	0	3	2	0	2	–
Indiana	L	RD	0	6	6	0	2	2	–
Minnesota	L	D	0	0	0	0	0	0	–
Oklahoma	I	RLD	0	0	0	0	0	0	–
California	I	D	(not examined)			0	0	0	–
Massachusetts	I	D	(not examined)			0	0	0	–
New York	I	D	(not examined)			0	0	0	–

* Key: R, river; I, impoundment; L, lake.
† Key: R, rapid sand filtration; S, slow sand filtration; L, lime or lime-soda softening; I, ion-exchange; D, disinfection.
‡ Plus sign indicates presence of cysts; minus indicated that none were found.
§ Impounded raw water from this river showed no nematode worms.

In Table 1 it can be seen that of the fifteen supplies taken from rivers, all but one contained live or dead nematodes in both the raw and the finished waters. Half of the supplies contain-

reduction in nematode population and four contained the same numbers of worms as the raw samples. Although live worms were found in all of the raw river water samples, four of the

finished-water samples showed dead worms only.

The highest nematode densities were observed in raw-water samples from a river in Texas and another one in West Virginia. No nematodes were found in the raw samples from the river in Michigan. The supply that drew raw water from a river after impoundment in Colorado showed a low nematode density in the river water but no worms in the impounded water. Although the concentration of nematodes in the finished water of this supply was two worms per gallon, only one organism was actually found in the volume examined. The concentrations of worms in the three samples from this supply cannot be considered significantly different from one another.

Although a few of the worms seen in the raw water were adults, all of those found in the finished water were larvae of various stages of development except the two male vinegar eels (*Turbatrix aceti*) which were present in the river water sample from Tennessee. The adults of this species range from 0.5 mm to 2.0 mm in length and from 0.05 mm to 0.08 mm in width; the larvae are 0.1–0.4 mm long and 0.01–0.05 mm in width.

One lake supply in Indiana contained small numbers of nematodes. None of the other five supplies that used impounded water and water from a lake in Minnesota contained nematodes in the finished-water samples. The finished-water sample from the California impounded supply was collected from a storage reservoir, and samples from the Massachusetts and New York impounded supplies were taken from taps of the distribution system.

The identified nematodes were assigned to the following genera in a decreasing order of frequency: *Monhystera*, *Aphelenchus*, *Rhabditis*, *Diplogaster*, *Cephalobus*, *Turbatrix*, and *Dorylaimus*. Three were unidentified because the specimens were lost during preparation for staining.

From the 11 specimens planted, four cultures of *Rhabditis*, *Diplogaster*, *Cephalobus* and a questionable *Cheilobus* were successful. One of the *Rhabditis* nematodes was tentatively identified as *R. limicola* and one of the *Diplogaster* as *D. nudicapitatus*. The *Cephalobus* culture was lost in the second transfer. The questionable *Cheilobus* resembled *C. quadrilabiatus* but its mixed morphological characteristics caused Vernon G. Perry, professor of nematology at the University of Florida, to suspect that it might be a new genus possessing features of two different families.

TABLE 2

Distribution of Free-Living Nematodes and Amebas in Water Supplies by Genera and Species

Organism*	No. of Supplies† Containing Organism	State Location
Nematodes		
Aphelenchus	3	W.Va.; Tenn.; Tex.
Cephalobus	2	Kan.; Ind.
Cheilobus quadrilabiatus‡	1	Wash.
Diplogaster nudicapitatus	1	W.Va.
Diplogaster	2	Ill.; Pa.
Dorylaimus	1	Md.
Monhystera	4	W.Va.; Mass.; N.Y.; Tex.
Rhabditis	3	Pa.; Md.; Tex.
Turbatrix aceti	2	Ga.; Tenn.
Unidentified§	3	Calif.; La.; Colo.
Amebas		
Naegleria gruberi	2	W.Va.; N.Y.
Hartmannella glebae	2	Kan.; Tex.
Hartmannella agricola	1	Tex.
Hartmannella rhysodes	1	Tenn.
Unidentified	2	Mass.; Md.

* Species included where known.
† All are river sources except for the Indiana source, which is a lake.
‡ Species identification uncertain.
§ Specimens lost in preparation for staining.

Of particular interest was the presence of a strong earthy or musty odor in the nematode cultures. As has been reported,[2] the odors of the cultures were indistinguishable from one another and were caused by a brownish, oily, gummy substance which could be extracted from the cultural fluid with benzene or carbon tetrachloride and produced a distinct odor when a drop of it was placed in a liter of water. The role played by nematodes in the odor of water supplies remains to be ascertained. Cobb,[5] as early as 1918, indicated that the free-living nematodes present in slow sand filters might affect the odor and taste of city water supplies.

Viable cysts of free-living amebas were present in finished-water samples from eight of the fifteen supplies that used river water exclusively as their source. No demonstrable cysts were found in seven supplies that used impounded or lake waters. Of the positive cultures, two were *Naegleria gruberi* and six were of the *Hartmannella* genus, four known and two unknown species. The cyst densities were quite low and fell in the range of 10–15 per gallon.

Discussion

The results of this investigation indicate that the presence of free-living nematodes in municipal water supplies in the United States is a relatively common phenomenon. This is particularly true of those supplies that use river waters as their source. Although it seems that the nematodes in finished water are of raw-water origin, one cannot exclude the possibility of their coming from breeding places established in the treatment plants or distribution systems.

Cobb[5] has reported that nematode populations of hundreds of millions per acre may be found in the top 3 in. of sand in a slow sand filter bed. In a recent study,[1] no nematodes were found in sand samples taken at various depths in the rapid sand filters, although nematodes were demonstrated to be present in the finished water. This, however, does not exclude the possibility of the nematode breeding in the gravels, where conditions are definitely more favorable for worm propagation than in the sand.

The presence of a relatively large number of nematodes in the river water in West Virginia confirms earlier observations on the same river in Ohio. Interestingly, the river on which the water treatment plant was located has been well known for its heavy pollution by domestic sewage. The fourfold reduction in nematode population in the finished water reflects the efficiency of the treatment processes.

It has been the experience of one of the authors that nematodes of the Rhabditidae family are frequently found in large numbers in trickling filters. A strain of *R. limicola* has been isolated from such a sewage treatment plant in Cincinnati[2] and a strain of *D. nudicapitatus* from a sewage treatment plant of the same type in Chanute, Kan.[6] A nematode identical to the questionable *C. quadrilabiatus* was also isolated from the effluent of a Chicago municipal activated-sludge sewage treatment plant. It has been further shown[7] that *D. nudicapitatus* and *C. quadrilabiatus* can ingest *Salmonella* and *Shigella* bacilli as well as Coxsackie and ECHO viruses, that 5–16 per cent of the ingested organisms can survive for 24 hr at 25°C, and that the nematode-borne organisms are com-

pletely protected against chlorination even when more than 90 per cent of the carrier worms are immobilized. These observations indicate that although the free-living nematodes are, by themselves, harmless when ingested, those of the Rhabditidae family can be of sewage origin and, therefore, carriers of pathogenic enteric bacteria and viruses. Although the chances that individual nematodes will ingest pathogens under normal conditions of sewage treatment are very small, the possibility of the nematodes being pathogen carriers deserves some consideration when significant numbers of them are carried by finished water. It is therefore suggested that the source of nematodes in finished waters containing more than 10 nematodes per gallon should be investigated and that remedial measures be effected.

The frequent presence of viable cysts of the free-living amebas in the finished water of those supplies using river waters is an interesting phenomenon. The value of their presence as indicators of treatment plant efficiency is not known at present, as the source of these cysts cannot be established with certainty. They might, however, be confused with cysts of *Endameba histolytica* in tap water during periods of waterborne amebiasis. Suspicious cysts found under such conditions should be identified by cultural as well as by morphological characteristics.

As the survey included only single grab samples from the various sampling points, one cannot attach great significance to the differences between the numbers of organisms found at one plant and those found at another, nor to the differences between the apparent removal efficiency of one plant as compared to those at others. In a previous study [1] large variations in nematode concentration were found at one supply during the period of the study, as well as marked variations in removal efficiency of the treatment plant. It would also appear that conventional treatment processes are not highly effective in removing or killing free-living nematodes.

Summary

The occurrence of free-living nematodes and amebas in municipal water supplies in the United States has been studied. The findings of the survey are:

1. Sixteen of 22 water supplies contained nematodes in both raw and finished water. Of the sixteen supplies containing nematodes, fourteen used river waters as their raw source and one used a river water after impoundment. Of the six supplies with no nematodes, four used impounded waters, one used lake water, and one used a river water for the raw sources.

2. Seven of the river waters showed nematode densities of more than 10 per gallon, the two highest being 30 and 38 per gallon. Two of these river water supplies showed no reduction in nematode density in the finished water.

3. The nematodes present in these supplies were assigned to the genera *Aphelenchus, Cephalobus, Cheilobus, Diplogaster, Dorylaimus, Monhystera, Rhabditis,* and *Turbatrix* (vinegar eel), of which the *Cheilobus, Diplogaster,* and *Rhabditis* have been found in large numbers in trickling filters.

4. One strain each of *C. quadrilabiatus, D. nudicapitatus,* and *R. limicola* has been isolated in pure cultures. A highly odorous, oily, gummy substance was liberated by these nematodes in cultures. It produced a distinct earthy or musty odor when one drop of the

oily material was diluted with 1 liter of water. The possible role played by these nematodes in producing odor and taste in water supplies has been discussed.

5. Eight supplies showed small numbers of viable cysts of free-living amebas of the *Naegleria* and *Hartmannella* genera in their finished water. All of these supplies used river waters as their raw source.

The possible sanitary significance of free-living nematodes in finished waters has been conjectured, because several members of the Rhabditidae family have been found in large numbers in trickling filters, and because some of the Rhabditidae are known to ingest pathogenic bacteria and viruses and to protect them against the action of chlorine. The sanitary significance and implications of viable cysts of free-living amebas in finished water could not be definitely established. The possibility of confusing cysts of free-living amebas with cysts of *E. histolytica* in suspected waterborne amebiasis has been emphasized.

Acknowledgments

The cooperation of health departments, water utilities, and USPHS regional office personnel in securing the raw- and finished-water samples is gratefully acknowledged. The authors are also grateful to G. Steiner, retired nematologist of the US Department of Agriculture, and to Vernon G. Perry, professor of nematology at the University of Florida, for their help in identifying some of the nematodes.

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Underground Waste Disposal and Ground Water Contamination

Task Group Report

A report of Task Group 2450 R—Underground Waste Disposal and Control, presented on Jul. 15, 1959, at the Annual Conference, San Francisco, Calif., by Lynn M. Miller (Chairman), Jones, Henry & Williams, Cons. Engrs., Toledo, Ohio. Other members of the task group were J. G. Ferris, A. G. Fiedler, G. E. Glover, C. E. Carl, W. N. Gahr, E. F. Gloyna, R. R. Kountz, G. W. Moore, and H. R. Wilke.

THE last report[1] by Task Group 2450 R pointed out the need for group work on a regional scale, in contrast to group work on a national scale, to study ground water contamination. To date, no regional study groups or task groups have been organized.

Task Group 2450 R was reorganized in 1958–59, with the addition of new members and the provision for greater geographic distribution of members and more complete reporting coverage. A new program of investigation was undertaken for the purpose of providing a yardstick of quality that could be better used to detect certain types of ground water contamination. The basic duties pertaining to the observation of, and reporting on, surface and subsurface liquid waste disposal were reaffirmed.

Trace Constituents

It was evident at the outset that the average chemical analysis of potable water supplies does not include determinations of ion concentrations that are not commonly objectionable in potable ground waters. Such concentrations usually represent the major mineral constituents of the geologic formations with which ground water is associated in its natural environment. Because of this, the concentrations are not relative to the quantity of elements available to the solution but to such factors as the pH of the water and the abundance of other soluble compounds that govern the complexity of the chemical environment.

The selection of suitable trace constituents is becoming increasingly complex and difficult because of the requirements for selection. Some of these are:

1. The element must occur in natural water-soluble compounds.
2. Concentration determinations must not be difficult or expensive.
3. The elements must be common enough to occur, to some degree, in most natural ground waters and a large portion of the probable liquid-waste contaminants.
4. The compounds of the element should be stable enough to avoid the formation of insoluble hydroxides or other compounds of low solubility when a change of environment occurs.

It is evident that the selection of proper elements for purposes of meas-

urement must entail considerable research and a large number of diversified scientific considerations. Much ground work is being accomplished by the Quality of Water Branch of USGS. It will be some time, however, before sufficient nationwide water sampling and studies will provide enough data for the particular purpose at hand.

Liquid-Waste Disposal

Much is being learned about the complexities of liquid-waste disposal by those who have the disposal problems. Various pharmaceutical concerns, paper companies, industrial metal processors, and small-parts manufacturers have encountered serious maintenance and procedural problems in the operation of a variety of raw-waste disposal facilities. The result has been that many new plant facilities are being installed with provisions for nearly complete treatment of liquid wastes before disposal. In some instances, the expense of this treatment may be partially offset by the savings realized through the recovery and reuse of chemical compounds in the waste solutions. In all such instances, the costs, when amortized over the period of plant use, indicate a savings over most disposal methods using injection or subsurface-discharge techniques.

Subsurface Disposal

The disposal of liquid wastes through wells has received considerable attention from industry and governmental agencies. The problems inherent in the process of injecting liquid wastes have been compounded by statutory restrictions.

Most wastes considered for subsurface disposal were so objectionable that it was thought sound policy to get them out of the way by planting. The fallacy of this philosophy becomes evident when potable ground waters show evidence of contamination and demonstrate that the liquid bodies do not always stay where they are planted. Statutory regulations and public opinion dictate the need for rigid standards regarding the construction of disposal wells and for careful selection of ground formations used for disposal.

Almost without exception, the approved disposal formations have relatively low porosity and permeability. For these reasons, formation plugging occurs with ease, and injection pressures attain hazardous magnitudes. To combat this situation, it is necessary to improve on original conditions of the wastes to provide a solution that is compatible with the physical chemistry of the formation and the fluids therein. The costs, 3 mills–½ cent per barrel, of clarifying, filtering, and general pH conditioning of the wastes usually necessitate serious consideration of the eliminaiton of deep-well construction and the required treatment to permit surface disposal of the effluents. Direct surface water disposals of toxic materials and other contaminants receive much scrutiny and are, therefore, seldom a long-term problem, unless such disposals have attained legal priority by virtue of extended practice.

Ground Surface Disposal

Statutory regulations against the continued dumping of wastes into surface water courses have forced many industrial plants, such as paper and food processing plants, to seek other methods of waste disposal. The seasonal operation of food-processing plants presents a considerable problem for the operation of normal treatment facilities. The large volume of waste

flows from both types of plants dictates the need for extensive treatment plant facilities. These factors have provoked much interest and investigation of ground surface disposal and natural diminution of high BOD's. The practices receiving the most attention are those of ponding for initial settling and spraying or ditch-spreading application to large land areas. Where possible, the land application practices have been coordinated with supplemental crop irrigation. The results have been quite successful and economical.

Some serious problems have occurred in Wisconsin and Michigan because inadequate investigation failed to reveal sufficient data concerning soil and water table characteristics. Some shallow well waters developed undesirable taste, odor, and color. In ground surface disposal, contamination results when the rate of waste application is in excess of the evaporation-transpiration requirements of vegetal cover, causing the applied waters, because of percolation, to extend beyond the limits of the disposal area. Controls over this condition should be exercised through the installation of shallow wells around the disposal area and regular sampling to detect changes in ground water quality.

Similar practices to dispose of wastes that have a heavy load of inorganic contaminants have been unsuccessful. Despite the research and investigations being undertaken by industry, rigid statutory control and regulations must be enforced to avoid the widespread use of ground surface disposal of wastes that cannot be dissipated through the natural or agricultural flora controls and processes.

Ponding and ground surface waste disposal continue to be the practices most hazardous to potable ground water supplies and should receive continued scrutiny.

Contamination by Domestic Wastes

Several instances of contamination by effluents from domestic waste-disposal systems have been recorded in previous reports from all parts of the United States. It was long anticipated that this source of contamination might become more troublesome as areas became more developed and the use of the disposal systems more widespread.

A JOURNAL article[2] on synthetic detergents in ground water relates the details of a study conducted in a residential area at Babylon, N.Y. The study was motivated by the appearance of synthetic detergents (syndets) in the individual domestic wells supplying homes in the area. Originally, attention was drawn to the area by the occurrence of hexavalent chromium contamination in one well that was situated about 400 ft from the waste discharge of a plating plant. Shallow sands and gravels permitted the rapid migration of the toxic chromium waste, which was first detected because of its color. Syndet contamination was suspected in neighboring wells because of taste, odor, and frothing conditions.

More than 180 private wells were sampled and travel distances for septic effluents determined. The time of syndet appearance seemed to be proportional to the distance of the wells from neighboring septic tanks. But protection against syndet contamination of wells is not insured by increasing this distance. Incidents on record indicate that syndets have traveled several hundred feet and have appeared in irrigation wells and domestic wells. There does not appear to be any deterioration of the syndet components with time or

distance of travel. For this reason, it is logical to assume that the time of syndet appearance is equally a function of distance, pumping rate, and geology of the area.

It is to be expected that more and more instances of syndet contamination will be discovered if the phenomenal increase in syndet use continues. Syndets now constitute more than two-thirds of all cleaning agents sold.

Statutory Trends

A report [3] presented at the Fourteenth Annual Purdue Industrial Waste Conference, on May 5, 1959, summarized several important facts concerning the statutory control of ground water pollution practices:

The Public Health Service has issued a "Suggested State Water Pollution Control Act." Thirty-five states have comprehensive state water pollution control statutes (vesting broad powers in a state agency subject to a court review) designed to control the pollution of all waters of the state without exception.

Much of the new activity in the field of statutory controls may have been motivated by the federal Water Pollution Control Act referred to by Stein.[3] Many states have considered financial inducements for compliance with the statutory controls, these inducements being in the form of tax relief to industries and direct aid to municipalities. In the near future, other states may employ a system of penalties for noncompliance.

Conclusions

Industries and legislative bodies are becoming more aware of the problems concerned with liquid-waste disposal and ground water contamination. Many problems are being eliminated, but new ones are developing. Much work must be accomplished and constant precautions taken to insure the continued satisfactory conditions developed by present facilities.

Standards should be developed for guides in evaluating disposal techniques and detecting unsatisfactory disposal practices. The increasing complexity of liquid wastes may require that standards be made flexible in order that they may be adapted to changing conditions.

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Test of Paints for Water Tank Interiors

John D. Keane and Joseph Bigos

A report of the Research Committee of the Steel Structures Painting Council, prepared by John D. Keane, Director of Research, and Joseph Bigos, former Director, both of Steel Structures Painting Council, Pittsburgh, Pa., with the cooperation of the Ambridge Water Authority, Ambridge, Pa., and the Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

IN 1950, the Steel Structures Painting Council (SSPC), the Ambridge Water Authority, and the Pittsburgh-Des Moines Steel Co., all located in the Pittsburgh area, cooperated in undertaking an extensive test of paints for use on the interior of water tanks. The purpose of this test was to evaluate the relative performance of several of the most serviceable conventional paint systems applied to surfaces that had been blast cleaned. Also evaluated were several of the vinyl paints available at that time.

A 1-mil gal open-topped steel tank, 84 ft in diameter and 25 ft high, was selected as the test site. It is located about 20 mi north of Pittsburgh, at Ambridge, Pa. The inside of the tank was divided into 54 panels. Each of the panels received a system consisting of some combination made up from twelve paint systems, two pretreatments, and ten methods of surface preparation. Descriptions of the paint systems are presented in Tables 1 and 2.

Surface preparation consisted of blast cleaning with several alternative types and sizes of abrasives (Fig. 1) in accordance with specifications SSPC-SP6-52T and, for small areas, SSPC-SP7-52T and SSPC-SP3-52T. Pretreatment consisted of either a vinyl washcoat or a phosphoric acid treatment. In all instances, the panels were blast cleaned and the pretreatment or primer applied before any detrimental rusting could occur. Paints were applied by brush and spray application in accordance with SSPC-PA1-53T. The bottom of the tank was cleaned by the Ambridge Water Department and painted the same as Panel 17. The tank was filled with water on Dec. 4, 1950.

Preparation of Test

1. Blast Section CG16 with chilled cast-iron crushed grit, size G16.

2. Spray on the chemical treatment and allow to dry. *Metal preparation* (No. 28) is made up of one part MP28 to two parts water; mix in a wooden bucket before applying with brush, mop, or dauber. Allow to dry for about 1 hr before sweeping off the loose white-gray powder prior to application of paint. *Wash primers* are made up of four parts pigmented vehicle to one part phosphoric diluent (mixing liquid). This mixture should be used within 8 hr or discarded.

3. Spray on first coat of paint (Amercoat is brushed on).

TABLE 1

Description and Rating of Paint Systems

Paint system	A		B		C		D			E	F	
Chemical treatment	WP 1	none	WP 919, 920	none	58768	none	WP 1	none	metal preparation 28	none	WP pass. 35	none
First coat	vinyl aluminum, 5221A		vinyl red lead, 915 light		vinyl aluminum, 59396		phenolic lead chromate			phenolic zinc dust–zinc oxide, Navy 52-P-67	phenolic red lead	
Second coat	vinyl leaded–zinc oxide, 5322		vinyl red lead, 915 dark		vinyl black, 59394		phenolic gray			phenolic gray	phenolic aluminum	
Third coat	vinyl aluminum, 5221A		vinyl alkyd aluminum, 929		vinyl aluminum, 59396		phenolic gray			phenolic gray	phenolic aluminum	
Paint manufacturer	Carbide & Carbon Chemicals Co.		Woolsey Paint & Color Co.		Glidden Co.		Mfer. 1*			Mfer. 2*	Mfer. 3*	
Thinner	5061		WP-butonol, 1001		S-59320, B-59571		mineral spirits			mineral spirits	WP 8000 (alcohol), FP-2000, A-4000 (turpentine)	
Blasting Material†	Panel Number and Test Rating‡											
OSS	1 (9.5)	2 (9.5)	3 (9.5)	4 (9.5)	9 (9.5)	10 (9.5)	6 (2)	7 (0)	8 (6)	5 (4)	11 (7)	12 (4)
Brush-off OSS	19L (9)						19R (0)					
Brush-off WB	20L (8.5)						20R (1)					
Brush-off BB	21L (9.5)						21R (0)					
Brush-off CG	22L (9.5)						22R (0)					
CG 25	23 (9.5)		24 (9.5)			25 (9.5)	26 (0)					
MG 16	27 (9)		28 (9.5)			29 (9.5)	30 (0)					
MG 25	31 (9)		32 (9.5)			33 (9.5)	34 (0)					
TS 550	35 (9)		36 (9.5)			37 (9)	38 (0)					
TS 460	39 (9.5)		40 (9.5)			41 (9.5)	42 (0)					
BB 16	43 (9.5)		44 (9.5)			45 (9.5)	46 (0)					
BB 25	47 (9.5)		48 (9.5)			49 (9.5)	50 (1)					
CG 16	53 (9.5)		54 (9.5)			51 (9)	52 (8)					

TABLE 1—(*contd.*)

Description and Rating of Paint Systems

Paint system	G	H	I	J	K	L
Chemical treatment	WP D102–7 D302–7	vinyl clear	red oxide No. 3, brushed	none	none	none
First coat	vinyl red lead, D102–9	vinyl white	aluminum vinyl No. 33	phenolic red lead TT-P86a-IV	phenolic zinc-chromate iron oxide	synthetic resin aluminum
Second coat	vinyl red lead, D102–9	vinyl white	gray vinyl No. 33	phenolic red lead TT-P86a-IV	phenolic zinc-chromate iron oxide	synthetic resin aluminum§
Third coat	vinyl white, D202–5	vinyl clear gloss	aluminum vinyl No. 33	phenolic red lead TT-P86a-IV	phenolic gray	synthetic resin aluminum§
Paint manufacturer	Gates Engineering Co.	Mfer. 6*	Amercoat Corp.	Mfer. 4*	Mfer. 6*	Mfer. 5*
Thinner	WP-D452–7, AC-D452–3	spray only	diluent No. 10, cleaner No. 12	xylol (or turpentine)	Sp. 1	mineral spirits
Blasting Material†	Panel Number and Test Rating‡					
OSS	13 (9.0)	14 (6.0)	15 (8.5)	16 (2)	17 (0)	18 (5)

* Numerical designations of manufacturers refer to SSPC listings.

† Key: OSS, Ottawa silica sand (flint shot); WB, thorough power-wire-brushing; BB, Black Beauty blast grit; CG, chilled cast-iron crushed grit, as normally used over and over at the Neville Island (Pittsburgh) plant (it has no definite grit size, but is a mixture containing G16 and finer material); MG, Hammerhead crushed grit; and TS, Tru-Steel shot. "Brush-off" means a commercially acceptable degree of cleaning; all paint coats were sprayed on the brush-off section.

‡ The ASTM ratings (designation D610) of Sep. 16, 1958, are shown in parenthesis below each panel number. A rating of 10 means perfect; 0, completely worn out.

§ One-half is sprayed on, one-half brushed on.

4. For each of the remaining panels, blast clean with the abrasive specified in Table 1. Apply the designated chemical treatment and first coat. Allow to set before blast cleaning the next panel.

5. Apply second coat of paint to all panels, being careful to spray the left half of each panel and to brush the right half. Half panels are about 29 in. wide.

6. Apply third (last) coat of paint to all panels, being careful to spray the left half and to brush the right half.

7. Clean, treat, prime, and finish paint the inner 64 ft of the bottom,

Fig. 1. Surface Preparation of Test Area

The outer ring of numbers designates the test panels (dotted lines) in each outlined portion of the tank. The area of each panel is about 160 sq ft, including the shell plus 10 ft of bottom. The letters and numbers in the next ring indicate the abrasives used to prepare the surface of each section of the tank. Key: OSS, Ottawa silica sand; BB, Black Beauty blast grit; CG, chilled cast-iron crushed grit; MG, Hammerhead crushed grit; and TS, Tru-Steel shot. "Brush-off" means a commercially acceptable degree of blast cleaning (SSPC-SP7-52T); all paint coats were sprayed on the brush-off section.

which has been utilized as a working area.

8. Allow paint to dry for about 5 days before filling the tank with water.

9. Inspect all panels at regular intervals, rating each ring in each panel and the bottom. The tank should be drained for these inspections.

Results and Conclusions

The test panels were inspected eight times—the last time on Sep. 16, 1958—by an inspection team of six men representing each of the participating organizations. In general, previous conclusions were confirmed: The vinyl systems were superior to all others tested, regardless of surface preparation (all blast-cleaned surfaces), pretreatments, or brand of material used; the phenolic systems, on the other hand, were nearly all in poor condition (Fig. 2). As had been noted previously, intercoat peeling had occurred during the first year. This failure had been attributed to the long period of time between applications of the first and subsequent coats. Such delay had no adverse effect on the vinyl systems, which are themselves dependent on proper application. Ratings of systems and comments on test results are given in Tables 1 and 3.

During the last inspection, it was observed that after 8 years of exposure to fresh water, an analysis of which is presented in Table 4, the vinyls have shown an extraordinary ability to resist corrosion. The only evidence of rusting is a slight blistering formation that occurred in 1954, but which has not increased since. All the vinyl paint systems performed well, regardless of manufacturer or type of vinyl paint, and regardless of whether or not wash primer was used.

The results of different methods of surface preparation, employing various types of abrasives for commercial blast cleaning and brush-off blast cleaning, show only slight variations. Even the power-wire-brushed surface is almost as good as the blast-cleaned surface, with very small failure occurring as a

TABLE 2

Paints Used in Test

Paint Number	Kind of Paint	Specification	Manufacturer
WPI	phosphoric wash primer	Bur. Ships No. 117, Coast Guard 52P1	Carbide & Carbon Chemicals Co.
XE 5229 A or 5322 (modified)	vinyl leaded-zinc oxide		Carbide & Carbon Chemicals Co.
XE 5221 A	vinyl aluminum		Carbide & Carbon Chemicals Co.
919/920	phosphoric wash primer	Bur. Ships No. 117, Coast Guard 52P1	Woolsey Paint & Color Co.
915 light	vinyl anticorrosive red lead	Bur. Ships No. 119, Coast Guard 52P4	Woolsey Paint & Color Co.
915 dark	vinyl anticorrosive red lead	(XE5295)	Woolsey Paint & Color Co.
929	vinyl topcoat aluminum	(XE5221A)	Woolsey Paint & Color Co.
GL58768	phosphoric wash primer	Bur. Ships No. 117, Coast Guard 52P1	Glidden Co.
GL59394	vinyl black	(XE5296)	Glidden Co.
GL59396	vinyl aluminum	(XE5221A)	Glidden Co.
Hysol 4080	phosphoric wash primer	Bur. Ships No. 117, Coast Guard 52P1	Houghton Labs.
Hysol 4201	vinyl aluminum	(XE5221A)	Houghton Labs.
Metal preparation 28	phosphoric rust inhibitor	Bur. Standard LC744	Neilson Chemical Co.
D102-2/D202-4	vinyl Durofilm clear		Gates Engineering Co.
D102-9	vinyl anticorrosive		Gates Engineering Co.
D202-5	vinyl Durofilm white		Gates Engineering Co.
No. 33	Amercoat red		Amercoat Corp.
No. 33	Amercoat gray		Amercoat Corp.
No. 33	Amercoat aluminum		Amercoat Corp.

TABLE 3—*Ratings of Paints and Comments on Test Results*

Panel Number	Type of Coating	Ratings* Sep. 16, 1958	Comments Jul. 9, 1956	Comments Sep. 16, 1958
1	vinyl	9.5	incipient blistering; rust on 1 rivet, 1st ring	complete protection in spite of numerous very small blisters
2	vinyl	9.5	incipient blistering; rust on 1 rivet, 1st ring	
3	vinyl	9.5	incipient blistering	
4	vinyl	9.5	incipient blistering	
5	phenolic	4	primer exposed, severe rusting	topcoat all peeled; most of primer peeled, surface rusted
6	phenolic	2	primer exposed, severe rusting	topcoat all peeled; most of primer peeled; surface rusted
7	phenolic	0	total failure	total failure
8	phenolic	6	primer exposed on 2nd and 3rd rings	topcoat failed on all 3 rings; primer, on 3rd ring
9	vinyl	9.5	incipient blistering	
10	vinyl	9.5	incipient blistering	
11	phenolic	7	1st ring, total failure; 2nd, 3rd, and 4th, some trouble at rivets; brushed panel in fair condition on all rings	blistering, especially at bottom, between coats; OK at top 3 rings
12	phenolic	4	1st and 2nd rings, total failure; 3rd and 4th, several spots where primer is exposed	poor intercoat adhesion
13	vinyl	9.0	incipient blistering; 1st and 2nd rings covered with fungi	
14	vinyl	6.0	topcoat peeling on all rings; 4th ring rusting	
15	proprietary	8.5	incipient blistering; few advanced blisters on brushed panel of 1st ring	numerous blisters, some with rust
16	phenolic	2	total failure	black; worse at top
17	proprietary	0	total failure	completely rusted
18	proprietary	5	advanced blistering and some rusting; brushed panel has severe rust on 2nd ring	2nd and 3rd rings bad; 1st and 4th OK
19R	phenolic	0	total failure	peeled, blistered, and rusted
19L	vinyl	9	incipient blistering; most rivets have rust spots	slight rust around rivet heads
20R	phenolic	1	total failure	
20L	vinyl	8.5	advanced blistering, some rusting	very slight rust on 2nd and 3rd rings
21R	phenolic	0	total failure	
21L	vinyl	9.5	advanced blistering	
22R	phenolic	0	total failure	
22L	vinyl	9.5	incipient blistering; 2 small rust spots on 1st ring	
23	vinyl	9.5	incipient corrosion	
24	vinyl	9.5	incipient corrosion	
25	vinyl	9.5	incipient corrosion; 4 rust blisters on 1st ring	
26	phenolic	0	total failure	lack of adhesion between coats; much rust
27	vinyl	9	general light pinpoint rusting on hand-brushed panel is worse than on sprayed panel	
28	vinyl	9.5	incipient corrosion; 1 rust blister on 1st ring of brushed panel	
29	vinyl	9.5	light rust stains on panel	
30	phenolic	0	total failure	topcoat peeled; primer wornout; rust, especially on right half
31	vinyl	9	incipient corrosion; general light rust stains and pinpoint rusting on panel	
32	vinyl	9.5	incipient corrosion, few light rust stains	
33	vinyl	9.5	advanced blistering, some rust stains	
34	phenolic	0	total failure	slightly better at bottom
35	vinyl	9	advanced blistering, few rust stains	slight rust spots
36	vinyl	9.5	advanced blistering	
37	vinyl	9	advanced blistering, few rust pinpoints	slight rust spots
38	phenolic	0	total failure	
39	vinyl	9.5	advanced blistering; 1 rust spot on 1st ring	slight rust on 2nd and 3rd rings
40	vinyl	9.5	incipient corrosion	
41	vinyl	9.5	advanced blistering	
42	phenolic	0	total failure	
43	vinyl	9.5	incipient corrosion on 1st ring	less blistering
44	vinyl	9.5	incipient corrosion	less blistering
45	vinyl	9.5	incipient corrosion	less blistering
46	phenolic	0	total failure	
47	vinyl	9.5	advanced blistering	
48	vinyl	9.5	incipient corrosion	
49	vinyl	9.5	incipient corrosion	
50	phenolic	1	total failure	
51	vinyl	9	incipient corrosion	
52	phenolic	8	2nd coat peeling on 2nd, 3rd, and 4th rings	topcoat peeled on 2nd and 3rd rings
53	vinyl	9.5	advanced blistering	
54	vinyl	9.5	advanced blistering	

* ASTM ratings are those shown in Table 1 (10 means perfect; 0, completely worn out).

result of the lifting of some pieces of rust scale that had not been completely removed.

Almost all the phenolic paint systems are in an advanced degree of failure. A considerable time had elapsed between the application of the first and second coats, as is often the case. The failure has, therefore, been attributed to the resultant lack of intercoat adhesion, which is a common problem with phenolic paints. It is not completely eliminated by the use of such strong solvents as ethylene glycol monoethyl ether * or methyl isobutyl ketone. Because delay between coats is frequently unavoidable in tank painting, SSPC believes that special attention should be given to overcoming the lack of intercoat adhesion in phenolic systems.

* Cellosolve, a product of Carbide & Carbon Chemical Co., New York, N.Y.

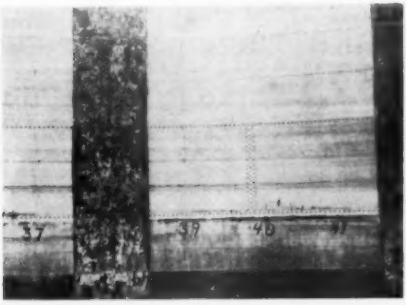

Fig. 2. Test Section of Ambridge Tank

Each test section is 24 ft high. The photograph shows the poor performance of Panels 38 and 42.

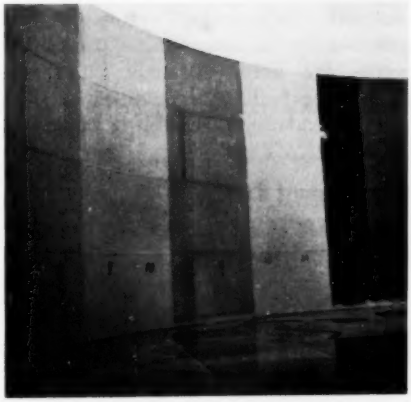

Fig. 3. Repainted Test Section

A portion of the tank was repainted in 1959, beginning Phase 2 of the paint test.

The success of the vinyl systems is attributed not only to good formulation but also to special care used in application. Solvent balance was apparently correct, and both dry spray and pinholing were avoided. Although the use of wash primer often affords more latitude in solvent balance, it was apparently not a critical factor in this

TABLE 4

*Analysis of Water Stored in Test Tank**

Month—1951	Hardness ppm	Alkalinity ppm	Residual Chlorine ppm	Chlorides ppm	Iron ppm	Manganese ppm	Temperature °F	pH
Apr.	86	47	0.60	16	0	trace	47	8.6
May	92	50	0.60	15	trace	trace	51	8.5
Jun.	99	58	0.64	14	trace	trace	60	8.5
Jul.	96	58	0.66	14	trace	trace	66	8.5
Aug.	105	61	0.64	18	trace	0.01 +	72	8.4
Sep.	104	58	0.62	19	0	0.01	74	8.4
Oct.	113	57	0.63	24	0	0.04	70	8.5

* Average values shown. Treatment of water prior to storage is with lime and ion-exchange softening. The water is filtered. The only floc is that produced by precipitated calcium carbonate. Chlorination is accomplished with chlorine dioxide and chlorine.

instance. When vinyl systems or any other systems containing volatile solvents are used, especially in closed tanks, the paint manufacturer's safety recommendations should be followed carefully.

Subsequent Test

It was decided that the twenty panels that had failed would be reblasted and repainted as soon as possible, using the most promising systems that are available (Fig. 3). Some of the vinyl systems still in good condition will be left unchanged, and others will be given an additional coat of maintenance paint. Among the new systems that will be applied is a phenolic system with various recoat times, made according to federal specification TTP86A IV; a coal-tar mastic; an inorganic zinc silicate, with and without a vinyl topcoat; another vinyl system; a zinc dust–zinc oxide phenolic; an epoxy system; an epoxy with vinyl topcoat; an amine-catalyzed coal-tar epoxy; an epoxy ester; an aluminum metallized panel; and a zinc metallized panel with vinyl sealers. This extension of the present test will be described in a separate report.

Acknowledgments

The paint test was conducted through the joint efforts of J. Z. Columbia of the Ambridge Water Authority; Robert Barclay and Robert Davis of the Pittsburgh-Des Moines Steel Co.; and Joseph Bigos, J. O. Jackson, J. D. Keane, and the other members of the Research Committee of SSPC.

Economic Aspects of Water Well Stimulation

Louis Koenig

A paper presented on Jul. 13, 1959, at the Annual Conference, San Francisco, Calif., by Louis Koenig, Research Consultant, San Antonio, Tex. This article is the second of a series on various aspects of well stimulation, presented in summary by the author at the Annual Conference. The first was published in the March 1960 issue of the Journal.

IN a previous article,[1] the results of a nationwide survey of water well stimulation were presented in terms of the technical performance of the technique. It was shown that water well stimulation generally is a technically desirable and successful practice. It remains to be demonstrated whether the practice is economically desirable. Various economic criteria may be applied, one of which is to compare the cost of stimulation treatment as an investment with the investment in the original well per unit of specific capacity (gallons per minute per ft of drawdown) achieved.

The criterion by which well performance is evaluated is its water productivity measured in gallons per minute. Productivity may be translated into terms of specific capacity to facilitate statistical comparison. Specific capacity may, in turn, be thought of as a measurable property of a well, which is created (or improved) by the investment of the construction cost or by investment in stimulation.

Costs of Stimulation

The costs of stimulation treatments vary widely. In this study, treatment cost is composed not only of the price paid for the treatment itself but also the cost of preparing the well for treatment and of restoring it to service afterwards. For example, for a shooting treatment, the cost includes the costs of pulling the pump or lifting it out of the way, the explosive itself, placing and shooting the explosive, cleaning the debris out of the well after the shot, and replacing the pump ready for service. In very few of the instances surveyed did the raw data provide this total cost. Reinquiry or, occasionally, estimates based on previous experience to determine, for example, the number of days and the type of rig and crew used in the cleanout process. The technique finally developed consisted of determining the physical parameters of the treatment job, such as the type of rig and crew used, the volume of acid used, the number of days spent in cleanout, and whether or not the pump was removed and replaced. To these components of the treatment job the unit prices as of 1959 for the particular area in which the well was located were applied. These included the hourly cost of labor, the cost of depreciation on the rig and other equipment, the standard cost for removing and replacing a pump, and the standard prices of well services obtained from the catalogs of well-servicing companies. Thus

a standard early-1959 treatment cost was obtained for each stimulation treatment, regardless of the year in which the treatment actually occurred.

The results of the cost analysis are shown in Fig. 1 as cumulative frequency distributions, according to the scheme used in the previous article.[1] The median costs for the various treatment methods are listed below.

Method	Median Cost $
Surging	380
Vibratory explosion	660
Pressure acidizing	950
All methods	1,050
Fracturing	1,250
Shooting	1,800

In Fig. 1, the approach to a straight line, shown by the heavy curve for all 716 treatments, indicates that deviations of any given ratio are equally likely above or below the median. Fracturing, vibratory explosion, and pressure acidizing do not follow the general slope to low percentages because these methods are ordinarily used by service companies who have a fixed base charge regardless of the size of the job.

It may be surprising that the cost of stimulation by shooting is the same as or greater than that of hydraulic fracturing. The former, because of the price of explosives and the short duration of the treatment itself, might be thought inexpensive, whereas the latter, with the heavy equipment necessary, might be considered among the most expensive. The discrepancy, for the treatments studied, lies in the cleanup time. Fracturing does not remove the loosened material from the formation, so that after the treatment it is necessary only to bail out or pump out the excess sand, which is a rather simple operation. In shooting, however, although the explosives are inexpensive, much debris is loosened and must be cleaned out of the well, and frequently in a form not readily pumpable. It seems illogical to blast a hole 3–6 ft in diameter in order to remove only ¼ in. of plugging deposit, necessary as it may be. The extreme of this, in one well surveyed the cost of explosives and shooting was $700, whereas the cleanout afterward cost $11,300.

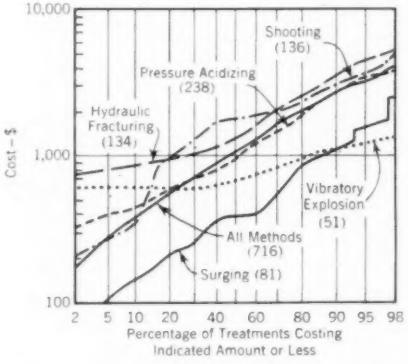

Fig. 1. Costs of Water Well Stimulation by Treatment Type

Each curve is a cumulative frequency distribution of 1959 costs in the survey sample for a specific stimulation technique. The number of treatments of each type in the sample is given in parentheses.

It is interesting to note that the first stimulation job in the oil industry was performed with explosives 100 years ago on the world's second oil well begun Aug. 31, 1859, 4 days after the completion of the Drake Well. Explosives continued to be used as the primary means of oil well stimulation for many years, but in the last quarter-century have lost ground to the more refined and efficient methods which now predominate.

Investment Cost Comparisons

To make an economic judgment concerning the value of water well stimulation, it is necessary to compare the method, by some common criterion, with other methods of achieving the same end. Toward this problem it was reasoned that the most usable criterion was the specific capacity of the well, which could be achieved in two ways: by well stimulation or by constructing another well. Therefore, it was decided to make an economic comparison between the cost of specific capacity achieved by treatment and the cost of specific capacity achieved by drilling the original well. This does not mean the cost of achieving specific capacity in new wells drilled in the same field, but by drilling the original well itself. This kind of comparison may, admittedly, sidestep the realities of a situation, if, for example, the unsatisfactory well to be treated is an anomalously poor producer in a field of otherwise good producers. In such a situation, the chances are that a new well, if drilled, would have the characteristics of the good producers rather than the anomalous well. Under those circumstances, the economically significant comparison is not one between treatment and another anomalous well, but one between treatment and the drilling of a normal well. In order to discover, however, which of the stimulation treatments corresponded to anomalous wells in otherwise good fields and determine the costs of the neighboring wells and the statistical chances of given specific capacities from them, would have been a task beyond the resources of the study.

Accordingly, it was decided to consider the relationship between two economic concepts. The first of these, the unit cost of specific capacity achieved by treatment, is obtained by division of the cost of treatment by the increment of specific capacity achieved. Correspondingly, another concept used was the unit cost of original specific capacity, obtained by dividing the cost of the well by the original specific capacity of the well. By these means, well costs and treatment costs can be reduced to common units and compared in terms of the property in which improvement is sought—namely, specific capacity. The concept that relates the former two, the unit-cost ratio, consists of the unit cost of incremental specific capacity divided by the unit cost of original specific capacity.

'Standard-Well' Costs

Although it was originally intended to use actual well costs, this proved impractical for two reasons: (1) many of the wells in the survey were constructed many years ago, and when the *Engineering News-Record* Construction Cost Index was applied to the costs of these older wells, it produced prices that were out of line with known current costs; (2) the well parts and construction items for which original costs were given varied widely among the wells surveyed. For example, the reported survey price might cover only the amount paid to the driller for making the hole whereas, on the other extreme, the price might cover such auxiliaries as land, landscaping, well house, or piping for connection to an existing transmission main. These auxiliary items, although pertinent to an economic comparison for any given well, could not logically be incorporated in a general comparison.

In place of the original cost, a computed cost for a "standard well" was used. This included the cost of the physical well, reasonable development at the time of completion as practiced in the area, and a 24-hr test pumping before the installation of a permanent pump. To obtain standard costs, unit prices for water well components were applied to the physical and standardized components of well construction. These unit prices, as of early 1959, were obtained by a survey among water well construction contractors in the areas where the surveyed wells were located. It was found that the country could be divided into a number of regions in which well construction techniques and unit prices were fairly homogeneous. The details will be reported in a subsequent article. It can, however, be said that by use of those few original costs which can be related to a standard well, one may construct a water well construction cost index. This index appears to approximate more closely the Building Cost Index than to the Construction Cost Index.

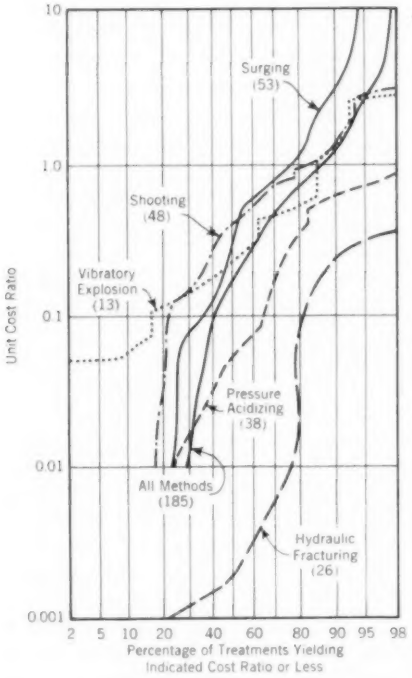

Fig. 2. Unit Cost Ratios of Various Stimulation Techniques

The figures in parentheses are for the number of treatments in the sample. Median unit cost ratios were: surging, 0.29; shooting, 0.38; pressure acidizing, 0.05; hydraulic fracturing, 0.0017; vibratory explosion, 0.20; all methods, 0.16.

Unit Cost Ratios

Figure 2 shows the cumulative frequency distribution of unit cost ratios by treatment. From the heavy curve for all types of treatment it can be seen that for the median improvement well, the specific capacity achieved by treatment cost only 16 per cent of the cost of specific capacity achieved by drilling the well in the first place. For fracturing, specific capacity has been achieved by treatment at a unit cost of only 0.2 per cent of the unit cost of the original specific capacity. Even in the most unfavorable instance, shooting, the incremental specific capacity has been achieved at only 38 per cent of the cost of that original well.

From the ordinate for a unit cost ratio of 1.0, it may be seen that fracturing and pressure acidizing almost never show a unit cost as high as that of the original well. Surging, however, shows a unit cost greater than that of the original well for about 23 per cent of the treatments. For all treatments combined, the unit cost of treatment is the greater for about 15 per cent of the cases.

Again, the order of increasing value follows approximately the same pattern as did the order for the technical performance criteria [1]—that is, shooting, surging, vibratory explosive, pressure acidizing and fracturing. It should be noted that the same reservations as to the nature of the sample, the approximate nature of specific capacity as a measure of performance, and other factors mentioned in the previous article apply here as well. The fracturing series contains a considerable number of treatments in which the original specific capacity was infinitesimal, and the cost of original specific capacity was therefore based on the specific capacity of normal wells in the same field. To that extent, the data for fracturing give a more conservative view of the economic advantage of stimulation than do the data for other techniques.

In Fig. 1, it can be seen that surging is the most economical method, and that shooting is the most expensive, if judged by the median. In Fig. 2, however, the unit cost ratios for both techniques are of the same general order. The reason is that surging, although low in cost, is even lower in effectiveness. Furthermore (although the data have not been analyzed to determine this), it is probable that surging is represented to a greater extent among rather inexpensive and shallow wells in unconsolidated formations. The unit cost ratios in Fig. 2 are presented as simple frequency distributions of a single criterion. The criterion, however, the unit cost ratio, can be represented as a compound function of certain other factors, one of which is itself a technical performance criterion for which the frequency distribution has been shown in Fig. 10–11 of the previous article.[1] Some insight may be derived from an examination of the unit cost ratio as a function of the technical performance criterion—that is, the fraction of original specific capacity restored (I/O ratio). The unit cost ratio may be expressed as $(C_t/C_w) \cdot s_o\ (s_a - s_b)^{-1}$, in which C_t is the cost of treatment, C_w is the cost of the well, C_t/C_w is the fractional cost, s_a and s_b are the specific capacity (in gallons per minute per foot of drawdown) before and after treatment, $(s_a - s_b)$ is the incremental specific capacity, s_o is the original specific capacity, and $(s_a - s_b)$ s_o^{-1} is the fraction restored. Favorable unit cost ratios are achieved when the fraction restored is greater than the fractional cost. The question to be resolved is whether the favorable unit cost ratios that come about in the frequency distributions shown are primarily associated with high values of fraction restored or with low values of the fractional cost. This can be explored by a graphical correlation between the fraction restored by any particular treatment and the unit cost ratio of that treatment. This is done in Fig. 3. It can be seen that, in the given sample, a low unit cost ratio is associated with a high fraction restored. The spread of the points at any one value of fraction restored represents the range of values of the fractional costs in the sample.

By inspection it can be seen that pressure acidizing and fracturing become uneconomical—that is, the unit cost ratio becomes greater than unity—if the fraction of specific capacity restored is less than unity. With vibratory explosion and surging, however, the economic limit is approximately 0.05, and it is 0.3 for shooting. In the range 0.1–1.0 for the fraction of specific capacity restored, the unit cost ratios of incremental specific capacity

are in the same range for all methods. The typical values are: surging, 0.15; vibratory explosion, 0.10; shooting, 0.30; pressure acidizing, 0.25; and fracturing, 0.25.

From Fig. 3 it is very noticeable that, in the sample, certain of the techniques result in high fractions restored and, therefore, low unit cost ratios.

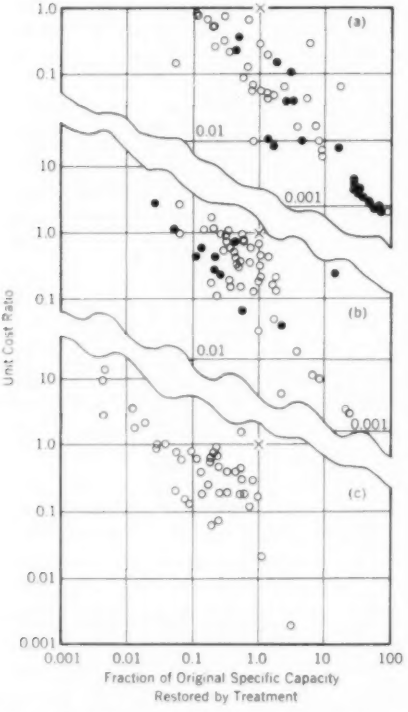

Fig. 3. Unit Cost Ratios of Various Stimulation Techniques by Fraction of Original Specific Capacity Restored

Part (a)—solid and open circles represent fracturing and pressure-acidizing treatments, respectively; Part (b)—solid and open circles represent vibratory explosion and shooting treatments, respectively; Part (c)—circles represent surging treatments only.

Other techniques show high fractions restored in only a few instances and, therefore, do not show favorable unit cost ratios. Fracturing, pressure acidizing, and shooting are in the former category whereas surging and (to a degree) vibratory explosion are in the latter. The division again seems to be between techniques ordinarily applied to consolidated formations and those applied to unconsolidated formations.

Conclusions

From the analysis of technical and economic data of the survey reported in this and the preceding article, it may be concluded that water well stimulation has shown highly favorable results, not only in its technical performance, but also by the economic criterion chosen. In the majority of instances, stimulation has added specific capacity at a unit cost less than the unit cost of the specific capacity produced by the original well. The median cost of improvement of even the least favorable method by this economic criterion occurs at a unit cost less than half the unit cost of the original specific capacity. This is not only important in regions of existing ground water exploitation; it is equally applicable and possibly much more important to the large areas in which there are adequate quantities of ground water contained in aquifers of such low permeability that ground water production from wells has not been economical. Wider knowledge and application of water well stimulation can potentially bring about a greater utilization of this segment of ground water resources.

Based on these analyses and results, the author recommends that water well stimulation be much more widely considered as a technique for developing ground water supplies. Such recom-

mendations should not, however, be made without a simultaneous mention of a number of quite legitimate limitations to the benefits of water well stimulation. The well production may not always be limited by the specific capacity and available drawdown, but, instead, by extraneous factors, such as avoidance of interference with other wells on adjacent properties, avoidance of intrusion of undesirable waters, or legal restrictions. Once such limits are reached, water well stimulation can be of no further influence in reducing investment cost per unit of production, although it can still function to reduce operating costs. The latter possibility will be described in a later paper.

Considerations of flexibility and standby facilities also enter in. If a well supply consists of only one well, then the choice between stimulation and construction of an additional well should be influenced not only by considerations of investment cost but also by the general desirability of having alternative facilities for flexibility and emergency. In bringing this restriction to bear in connection with the survey data, it should be recalled that the investment cost for the original well in the present study does not include the pump and a large number of additional facilities that are necessary before a well can become a water supply. To that extent, the comparisons, specifically those of unit cost ratios, are very conservative. If an *additional* well is contemplated, the actual economic advantage of stimulation of an existing well will be found to be much greater.

Acknowledgment

Acknowledgment is due the Halliburton Oil Well Cementing Co. for professional and financial support, as well as to the numerous other groups and individuals who have aided in this work. In addition the author expresses his gratitude to the well construction contractors who supplied the information on unit prices used in setting up the standard well costs.

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Effects of Soil Corrosion on Cast-Iron Pipe

Hugh L. Hamilton

A contribution to the Journal by Hugh L. Hamilton, Pres., A. V. Smith Eng. Co., Narberth, Pa.

IN 1945, AWWA, in cooperation with NEWWA and the Institute of Water Supply Utilities, published a summary of a survey of water supply facilities in 26 cities in the United States and Canada.[1] The records of these cities were examined to determine the expected life of various facilities. Included in the survey were data on approximately 56,000,000 ft of cast-iron water distribution mains, ranging in size from 4 in. to 60 in. The first of the mains was laid in 1817. At the time of the survey, 91.3 per cent of the cast-iron mains were still in service. As can be seen in Fig. 1, of the mains taken out of service, most were 4 in., a size that was eliminated primarily because of fire protection requirements. If the 4-in. main is not included, 96.1 per cent of all cast-iron pipe, in the 26 cities studied in 1945, is still in service. This is a remarkable record for any construction material. According to corrosion theory, so imposing a performance record, particularly when one considers the wide variety of environments to which these mains have been exposed, would have been difficult to predict.

Supplementary Surveys

In order to arrive at a better understanding of the underlying mechanisms involved, the Cast Iron Pipe Research Association recently undertook two supplementary studies [2, 3] to determine the effect of soil corrosion on cast-iron pipe. Studied in these surveys, conducted during 1956 and 1957, were eight cities located in different parts of the United States. Among these eight cities were four included in the 1945 survey. It was decided to limit the studies of these four cities to the oldest known cast-iron pipe. In the other four cities studied in the 1957 survey, it was decided to include samples of relatively new (25 years old), as well as old, cast-iron pipe. In all cities, the most corrosive environment was sought.

Essentially the purpose of the surveys was to evaluate the effects of soil on the serviceability of cast-iron pipe. The cities chosen are located in areas representing six of the seven major soil classifications as defined by Marbut.[4] The work was also undertaken to add further meaning and significance, through engineering data, to the figures established in the 1945 survey. The major soil groups, according to Marbut, and the locations of the cities studied are shown in Fig. 2.

In carrying out this work, the corrosion engineers assigned to the job were faced with a number of separate problems. First, it was necessary to examine the records of the utility to establish the areas in which pipe of known installation dates existed. The primary interest was in the oldest water mains still in use. After establishing main locations and installation dates, the corrosion engineers were required

to conduct a field survey to determine the general corrosive character of the soils in the areas where pipe of the desired age was located. After what were considered to be the most corrosive areas were established, preferably involving natural soil conditions, examinations had to be made of available records pertaining to street railway operation and electrolysis mitigation systems that might have existed in the past. Further, every effort was made to locate cathodic protection installations that might, under any circumstances, influence underground structures in the areas selected. After the most meaningful location for further examination was established, one length of the cast-iron pipe was exposed for direct physical study. As a final requirement, a small section of the main was removed to permit chemical and micrographic examinations.

Survey Tests

Various tests were performed during the surveys. When the most desirable locations, from the standpoint of pipe size and age, were established, a general survey of the soil conditions was made in the indicated areas. One of the tests employed was a measurement of the electrical resistivity of the soil in the vicinity of the main. This was accomplished through the use of a soil resistivity rod. Fundamental corrosion theory dictates that the electrical resistance of the corrosion path has a bearing on the rate of the corrosion that may be anticipated. It should be kept in mind that although this information is of significance in itself, it is only one of the many factors that the engineer must consider. Thus, in general, low-resistivity soil—that is, soil offering a low resistance to the flow of electrical current—is one promoter of

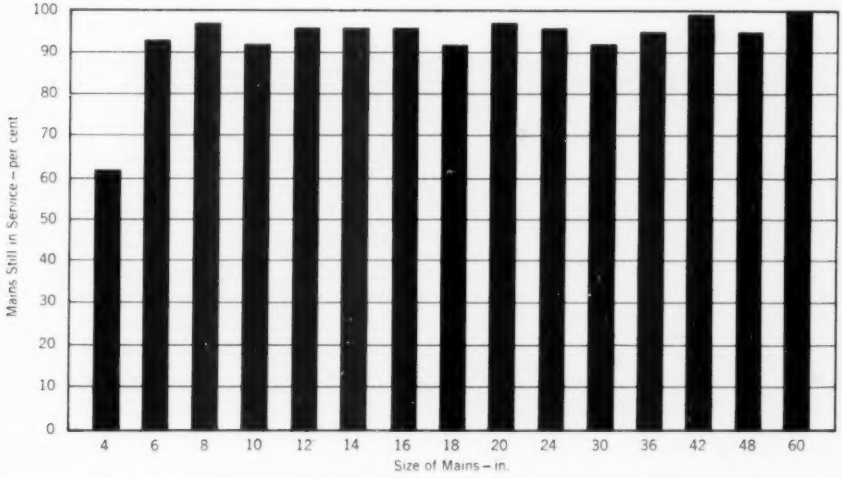

Fig. 1. Previously Surveyed Cast-Iron Mains Still in Service

If the 4-in. pipe is not included, 96.1 per cent of all cast-iron mains, in the 26 cities surveyed in 1945,[1] are still in service.

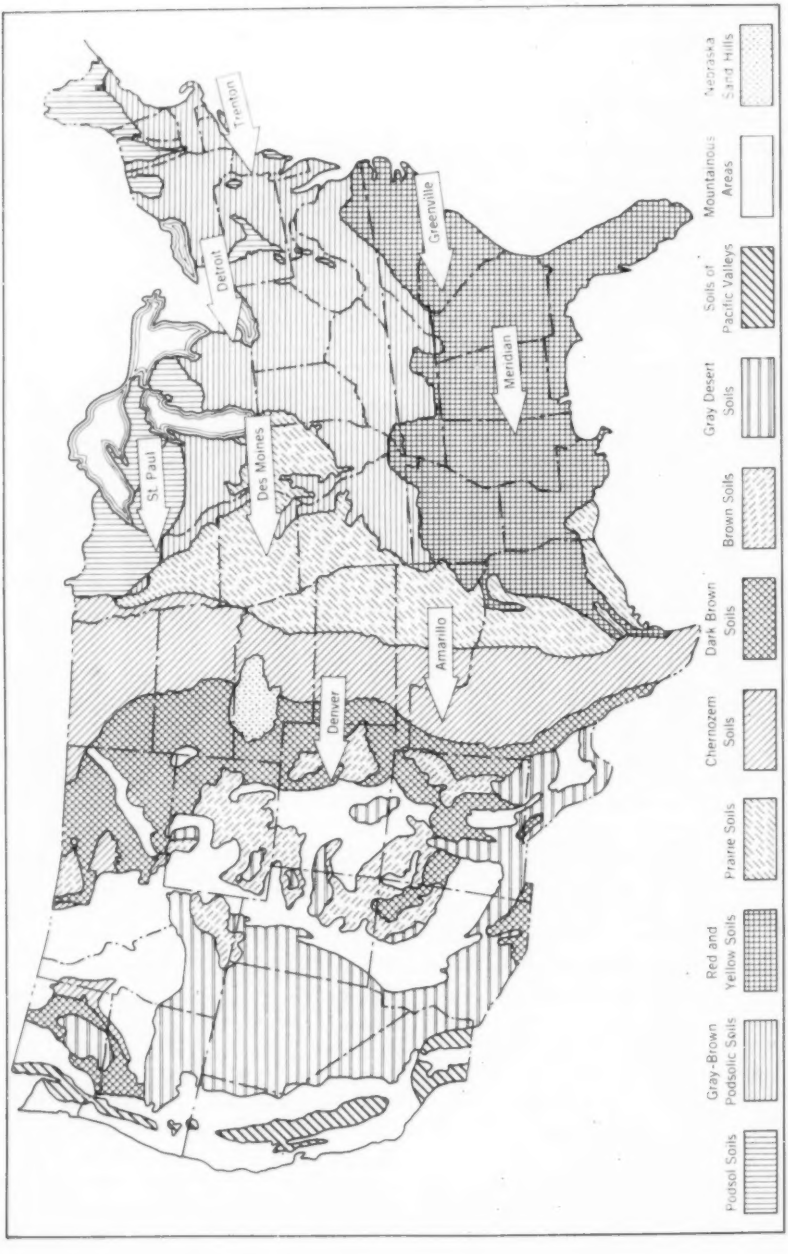

Fig. 2. Major Soil Groups in the United States and Location of Cities Studied

corrosive activity. Further, changes in electrical resistivity from one point in an area to another can be indicative of changing concentrations of salts in the soil. Differences in salt concentrations can produce galvanic currents along the pipeline. Thus, for the location of the most corrosive areas, emphasis was placed on low resistivity and local variations in resistivity.

In addition to measurements of resistivity, samples of soil at pipe depth were taken with a soil test probe. A small quantity of the soil was thus made available for first-hand examination. It was then possible to determine, among other things, whether the soil was a clay, a sand, or a loam, whether it was generally wet or dry at pipe depth, and what its pH value was. The chemistry of the soil and its particle size and arrangement all have significance in an analysis of the potential corrosiveness of the soil. To date, the science of corrosion engineering has not developed these specifics enough to permit rigorous scientific analysis. The experience and alertness of the investigating engineer must be relied upon. Similarly, soils exhibiting extremely low or extremely high pH—that is, extremely acid soils and extremely basic soils—are indicative of soils that have been found to be corrosive. On the basis of these tests, a selection was made of the most suitable location for excavation of the main.

Generally speaking, the particular site selected for the test had, in the opinion of the engineers, the most corrosive conditions in the area, from the standpoint of the soil present. Further, when a selection had been made, the location was studied to determine if it had a history of stray-current electrolysis. All available records pertaining to trolley line operations, cathodic protection installations, and any other possible direct-current sources were considered in order to determine if they had any effect on the particular area under consideration. When the section of pipe was excavated for inspection, the exterior surface was carefully examined by the investigating corrosion engineer before the removal of the last adhering soil deposits. This was done in order to determine the type of soil with which the main had been in intimate contact, the products of corrosion, and the corrosion pattern. After the pipe was thoroughly cleaned with heavy wire brushes, it was examined for any penetration by corrosion. Particular care was taken to see that any graphitic corrosion of the surface was removed, so that a true evaluation of the depth of penetration could be made.

TABLE 1

Relative Corrosiveness of Soils

Classification of Soil	Maximum Penetration of Cast Iron* *mils/yr*
Noncorrosive	0–5
Mildly corrosive	5–15
Moderately corrosive	15–25
Corrosive	25–35
Very corrosive	35–45
Extremely corrosive	>45

* Average rate.

Another test at the time of excavation was the measurement of the reduction-oxidation potential of the soil in the immediate vicinity of the main. This was made as quickly as possible after the excavation had reached pipe depth. In this type of measurement, use is made of the fact that soils having various reduction-oxidation characteristics exhibit different and reproducible potentials. Thus, it is theoretically possible, after measuring the potentials, to obtain an indi-

cation of whether the soil is oxygen deficient or well aerated. Certain bacteria that cause extensive corrosion damage exist in oxygen-deficient areas. Such areas exhibit an extremely low reduction-oxidation potential, as do areas in which corrosion occurs from differential oxygen concentration.

With the pipe exposed, a direct electrical connection could be made to it. At this time, the measurement of the electrical potential between the pipe and soil was made with a saturated copper–copper sulfate half-cell. This was done for two reasons: first, to determine whether or not any stray direct currents from operating trolley systems or other sources were presently in evidence at the location and, second, to get an approximation of

TABLE 2

Soil Conditions—1956 and 1957 Surveys

City	Approximate Area of Survey *sq mi*	Avg Soil Resistivity *ohm-cm*	Great Soil Group*	Soil at Excavation Site				
				Resistivity *ohm-cm*	Type of Soil	pH	Redox Potential *v*	Relative Corrosiveness
Des Moines, Iowa	1	3,700	prairie	1,100–1,500	gray clay with sand inclusions, wet	6.5–6.9	+0.163–+0.170	corrosive
Denver, Colo.	4	5,500	dark brown and brown	3,000–5,000	sandy loam, dry	6.5–6.9	+0.475–+0.560	mildly corrosive
St. Paul, Minn.	1	11,400	podsol and gray-brown podsolic	500–1,100	clay mixed with organic matter, wet	6.2	+0.109	very corrosive
Detroit, Mich.	1	990	gray-brown podsolic	350–500	dense blue and brown clays, moist	6.8–6.9	−0.104–+0.507	very corrosive
Trenton, N.J.	8	16,300	gray-brown podsolic	5,000	sandy loam, moist	6.1	+0.518	mildly corrosive
				9,000	sandy loam, some cinders, moist	8.1	+0.487	mildly corrosive
Amarillo, Tex.	7	1,130	chernozem	2,380	loam with overlay of white clay, dry	7.8	+0.783	mildly corrosive
				2,500	fine loam, dry	7.4	+0.545	mildly corrosive
Meridian, Miss.	4.5	5,450	red and yellow	6,070	heterogeneous loams and clays, wet	3.6	+0.540	moderately corrosive
				24,500	homogeneous sandy loam, dry	5.2	+0.465	noncorrosive
Greenville, S.C.	5	15,800	red and yellow	6,225	heterogeneous red clay with sand and cinders, moist	6.3	+0.689	mildly corrosive
				17,300	heterogeneous clays, moist	6.1–7.2	+0.653–+0.724	mildly corrosive

* According to Marbut.

the residual potential to a reference half-cell. After this, a measurement was made to establish the electrical resistance of an exposed pipe joint. The data obtained were analyzed and a decision reached with regard to the indicated corrosiveness of the soil at the site of the excavation. This decision was based on the analysis of the various properties of the soil. The soil-corrosiveness rating was not based on the condition of the cast-iron pipe excavated; instead, the rating was an indication of the degree of corrosion that one would expect to find in soil having the properties observed. For comparative purposes in this study, the relative corrosiveness of soils is defined in Table 1.

Pipe and Soil Conditions

Data on pipe and soil conditions were obtained at the various excavation sites in the eight cities studied. Table 2 shows data on soil and environmental conditions; Table 3 gives the condition of pipe as determined after excavation and examination.

The pipe excavated in Des Moines, Iowa, was a 6-in. static-cast pipe, installed 85 years prior to the survey. After examining the pipe, the engineers reported: "Pipe in sound condition; mild overall loss of iron at pipe surface; no indication of corrosion failure in foreseeable future." The soil was damp and had a low resistivity, a neutral pH, and a low potential. These conditions are indicative of aggressive galvanic and bacteriologic corrosion. The soil was rated as corrosive. No measurable pitting was found, even though a complete penetration of the pipe was expected.

At Denver, a 71-year-old, 4-in. pipe was examined. The report states: "Pipe in excellent condition, equivalent to new pipe." The soil in this area had an average resistivity of 4,000 ohm-cm, was neutral in pH, and exhibited a high redox potential. It was rated as being mildly corrosive. A maximum penetration of 0.355 in. would have been a conservative estimate of the pitting in this environment for the time of exposure. It was possible to examine a number of samples of cast-iron pipe that had failed because of extensive corrosion in service, these samples having been carefully labeled as to the locations and the dates of the failures. Five of these samples were taken at random and an examination made of the locations at which the failures had occurred. In every instance, without exception, the location was in the immediate vicinity of a former substation used to power the local trolley system. Examination of the corrosion patterns on the samples confirmed the opinion that the failures had been the result of stray-current electrolysis rather than of local soil corrosion.

The pipe examined in St. Paul was a 6-in. sand-cast specimen with 85 years of service. It was described by the engineer as: "Pipe in sound operating condition; scattered pitting to approximately 50 per cent penetration; possibility of failures in 30–50 years." The soil was heterogeneous, containing clay, sand, small rocks, and organic matter, and was in a wet area. It exhibited a resistivity of 500–1,100 ohm-cm at pipe depth and had a low (+0.109-v) redox potential and slightly acid pH. The soil was classed as very corrosive. In spite of the fact that a maximum pitting depth far in excess of the wall thickness could be expected, the deepest pit found on the 12-ft length of pipe exposed was 0.330 in., slightly more than 50 per cent penetration. Thus, the actual average

rate of pitting was 4 mils per year, as opposed to the expected rate of 35–45 mils per year.

The situation at Detroit was quite similar to that at St. Paul. A 10-in. pipe, 102–118 years old, was excavated and examined. It was described as: "Pipe in generally excellent condition; no indication of corrosion failure in the foreseeable future." The soil resistivity in the ditch was 350–500 ohm-cm. The soil was a mixture of moist blue

TABLE 3

Condition of Excavated Pipe—1956 and 1957 Surveys

City	Main Size *in.*	Depth of Main *ft*	Age of Main *yr*	Maximum Penetration* *mils/yr*	Potential to Saturated Cell† *v*	Joint Resistance *ohms*	Corrosion Products	Condition of Pipe
Des Moines, Iowa	6	7	85	trace	0.430	0.000256	sulfides, graphite	sound
Denver, Colo.	4	4.5	71	trace	0.545	0.00166	red oxides of iron	sound
St. Paul, Minn.	6	6	85	4.1	0.605	0.00521	sulfides, graphite, white hydroxides of iron	serviceable‡
Detroit, Mich.	10	5	102–118	2.2	0.607	0.01384	sulfides, white hydroxides, graphite	sound
Trenton, N.J.	6	5	33	trace	0.680	no bell excavated	sulfides, white hydroxides, graphite	sound
	6	4	21	trace	0.590	0.00102	sulfides, graphite	sound
Amarillo, Tex.	6	3	56	trace	0.335	0.035	oxides of iron, graphite	sound
	6	4	21	trace	0.545	0.0152	none	sound
Meridian, Miss.	6	3.5	70	trace	0.660	0.000652	sulfides, graphite,	sound
	8	2	18	trace	0.545	0.000428	trace of graphite	sound
Greenville, S.C.	12	7	52	trace	0.470–0.525	0.000233	red oxides of iron	sound
	6	2.5	23	4	0.554	0.00121	graphite, sulfides	serviceable

* Calculated average rate.
† Copper–copper sulfate cell; pipe terminal negative.
‡ 30–50 years to penetration.

and brown clays with some sandy inclusions, had a neutral pH, and exhibited an extreme range of redox potentials (−0.104 to +0.507). It was classified as very corrosive. Tight pitting was observed, with one random pit of 0.240 in.

In Trenton, N.J., two sections of pipe were examined, one 33 years old, the other 21 years old. The soil was considered only mildly corrosive, having resistivity readings of 5,000 and 9,000 ohm-cm at the respective excavations. With regard to the older pipe, the soil was sandy, with pockets of greenish clay, and classified as mildly corrosive. The newer pipe was in a filled area containing a heterogeneous mixture of sandy loam, cinders, and refuse. It was also classified as mildly corrosive. The condition of both was described as excellent.

The two sections of pipe examined in Amarillo, Tex., were 56 and 21 years old, respectively. The older pipe showed a shallow, general graphitic surface, with sound metal beneath. No isolated pits were found. The newer pipe was found to be in excellent condition, with no measurable pitting. The soil in both instances was homogeneous, fine, brown loam, very dry at the time of the survey. There was a general overlay of white clay in the area. The resistivity was 2,380–2,500 ohm-cm, with a slightly alkaline pH and a high, positive redox potential. The soil was classified as mildly corrosive at both sites.

In Meridian, Miss., an area of intense annual precipitation, two sections of pipe were examined. One, a 70-year-old 6-in. pipe, was in wet, heterogeneous clay, with a resistivity of 6,070 ohm-cm and an acid pH of 3.6. Some slight surface graphitization had occurred on this pipe, but no measurable pit penetration was found on cleaning. The soil was classed as moderately corrosive. The newer pipe was in a homogeneous red loam, in a relatively dry area. Soil resistivity was 24,500 ohm-cm; the pH, a slightly acid 5.2. The soil was classified as noncorrosive.

In Greenville, S.C., the predominant soil is a red clay with a relatively high resistivity. A 52-year-old pipe and a 23-year-old pipe were examined. Both were in excellent condition. The newer pipe was in a clay area with a resistivity of 17,300 ohm-cm and a slightly acid pH. Some scattered pitting was found, and a maximum rate of penetration of 4.1 mils per year was calculated. The older pipe showed no measurable pitting and was in a heterogeneous fill, having a resistivity of 6,225 ohm-cm. Both soils were classed as mildly corrosive. The actual condition of the pipe was far better than could be expected if the environment alone were considered.

Conclusions From Surveys

As a consequence of the two surveys, a number of conclusions can be made:

1. In the selected cities, the old cast-iron pipe is located in areas that have been subjected to stray traction current. In every city, the operation of trolleys in the areas where the studies were made has been abandoned. It is presently impossible to evaluate, beyond reasonable assumption, the earlier effects of trolley operations.

2. The soils included in the two surveys span a wide range of properties and are representative of the soils in parts of the United States where extensive experience with cast-iron pipe is a matter of record.

3. The primary cause of the active corrosion found is attributed to the

action of anaerobic sulfate-reducing bacteria in very localized areas.

4. All the pipe examined was found to be in sound operating condition, in spite of corrosive soil conditions in many instances.

5. The engineering data obtained from eight widely separated cities indicate that there are substantiating facts to support the opinion that old cast-iron pipe has an inherent resistance to corrosion. The mechanism by which this apparent resistance is achieved is still to be determined.

6. In the cities where both static-cast and centrifugally cast pipe were examined, there was no apparent difference in the rate of corrosion of pipe made by either old or new techniques. By empirical standards given, soils for these areas are rated from noncorrosive to moderately corrosive.

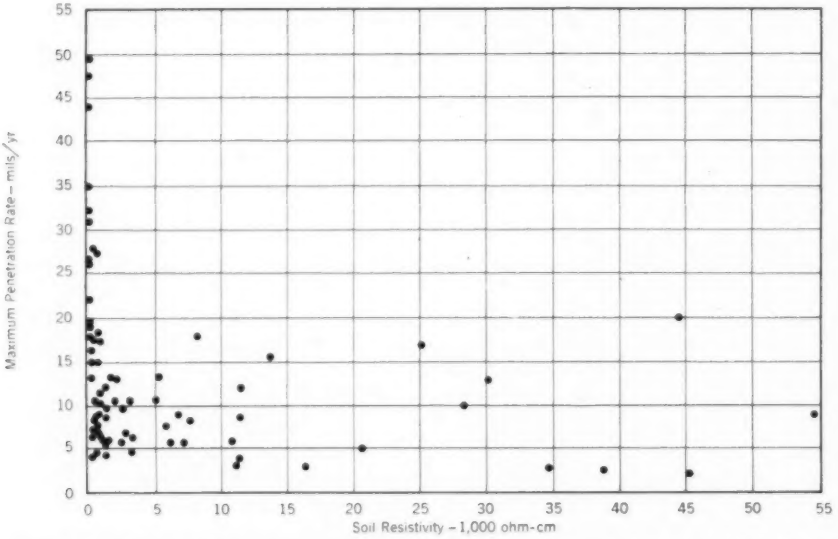

Fig. 3. Relationship Between Maximum Penetration of Pipe and Soil Resistivity

Not until the soil resistivity drops to approximately 700 ohm-cm is there any evident relationship between pitting and resistivity.

Corrosion Tests

Some of the corrosion studies made by various groups investigating underground corrosion merit discussion. Perhaps the best known of all the soil corrosion test programs is that of the National Bureau of Standards, conducted at many test sites throughout the United States. In these tests, more than 36,000 specimens representing 333 different ferrous and nonferrous pipe materials were exposed in 128 test locations. Included among the materials tested were many samples of 6-in. cast-iron pipe. The results of these tests have been published by the National Bureau of Standards.[5] At various times, the work at the bureau was supported by corrosion committees from other interested organizations, including the Cast Iron Pipe Research Association. Throughout this pro-

gram, many conferences were held for the purpose of bringing together various delegates to discuss and exchange information relating to underground corrosion. As the program progressed, it became evident that there was a marked difference in the corrosion characteristics of various soils. Thus, in some soils, penetrations of pipe walls were observed to occur after a relatively short exposure, while at other locations corrosion was hardly detectable.

As this work proceeded, tabulations were made for the various test sites of such factors as the internal drainage, soil resistivity, pH, composition of water extracted from the soil, mean temperature, and annual precipitation. The test samples themselves were removed periodically from the various sites and sent to a central collection point in Washington, D.C., where the samples were carefully cleaned of corrosion products and weighed, and the pit depths measured. In this way, the important data were tabulated for each material in any given site.

If the data pertaining to cast-iron pipe samples are examined, it is interesting to note the relationship between soil resistivity and pit depth after a period of time. Figure 3 shows the data on maximum penetration rate, based on a 10-year period, as related to soil resistivity. Not until the soil resistivity drops to approximately 700 ohm-cm is there any evident relationship between pitting and resistivity; and even below this value, there is a wide scattering of plotted values. The data indicate that in many instances the maximum penetration rate for resistivities less than 5,000 ohm-cm is less than

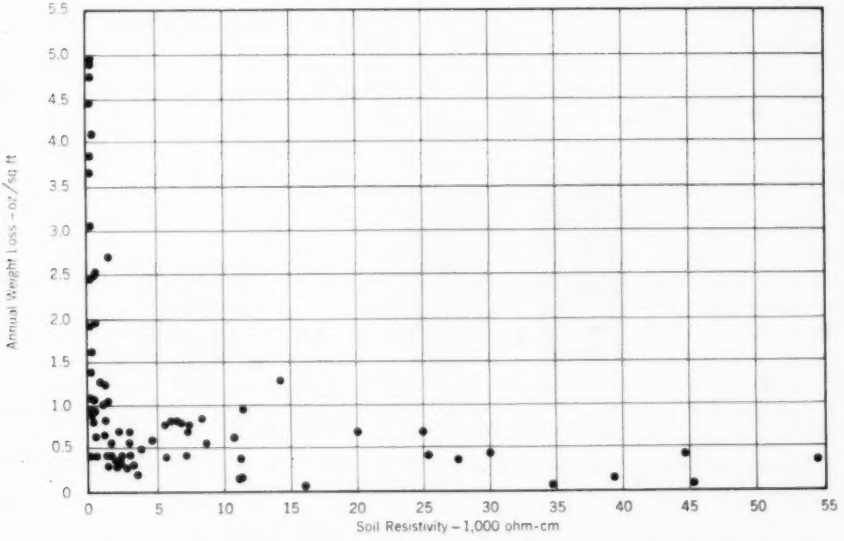

Fig. 4. Relationship Between Loss of Pipe Weight and Soil Resistivity

As with plots of maximum penetration and soil resistivity, there is little relationship between weight loss and soil resistivity, until values less than 700 ohm-cm are reached.

that for resistivities as large as 50,000 ohm-cm. As pointed out earlier, soil resistivity has long been used by corrosion engineers to predict corrosive areas. Thus, with regard to corrosion of isolated cast-iron pipe, it seems that soil resistivity alone has very little meaning unless it falls in an extremely low range (less than 700 ohm-cm); and even in this range, the greatest number of corrosion values fall in the same range as that for soils of higher resistivity.

Another corrosion effect studied by the Bureau of Standards concerns the general loss of weight as it relates to soil resistivity. Figure 4 shows this relationship for data averaged over a 10-year period. As with plots of maximum penetration and soil resistivity, there is very little relationship between weight loss and soil resistivity, until values less than 700 ohm-cm are reached. Again there is a wide scattering of values in this low range, although in some instances weight loss appears to increase quite rapidly with the decrease in soil resistivity.

The data plotted in Fig. 3 and 4 represent average rates calculated at the end of a 10-year period. The data of the Bureau of Standards indicate that corrosion rate is frequently not a linear function of time. Generally, the initial corrosion rate is appreciably higher than the rate after a period of exposure; therefore, the data plotted on the basis of the average for the first 10 years may be inaccurate for predicting long-range behavior. The actual time required for penetration may be considerably longer than the data indicate.

Strength of Corrosion Products

Another important question concerns the strength of corrosion products and their value in maintaining pipe as a useful transport facility. As a part of its research program, the Cast Iron Pipe Research Association conducted numerous tests to determine the physical strength of cast-iron pipe corroded by various environments. Figure 5 shows the bursting strength of a number of sample specimens buried for 16 years in a cinder fill in Birmingham. The fill was essentially a chemical environment employed to accelerate corrosion. The samples were removed from the test yard, brought aboveground, pressure tested to destruction,

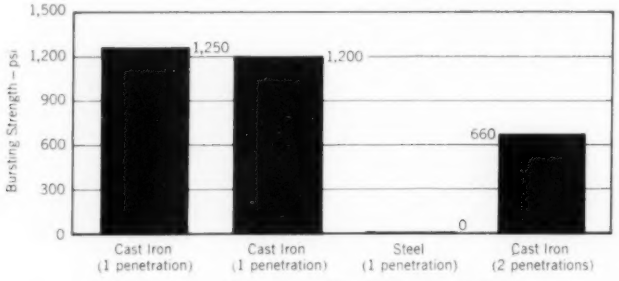

Fig. 5. Bursting Strength of Corroded Pipe

The data are from test results of burying pipe samples in cinders for 16 years to accelerate corrosion.

then carefully cleaned so that the surface of the metal could be examined. The steel pipe, which had one hole, had no bursting strength. The cast-iron samples, which also had one or more holes, still retained considerable bursting strength. The weakest, which had two holes, actually withstood 660 psi, about six times the pressure required in service. Thus, it is evident that the products of corrosion in cast-iron pipe have an ability to retain the strength of the pipe.

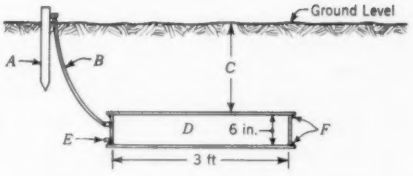

Fig. 6. Test Bomb Installation

Key: A, *stake, to hold tube in place;* B, ¼*-in. copper tube;* C, *depth of burial, same as for test specimens of the Bureau of Standards;* D, *test bomb;* E, *plug; and* F, *steel plates, welded or brazed in pipe at both ends.*

Test Bombs

Because the foregoing test of corroded pipe involved the actual removal of the samples from their natural environment and required the destruction of the sample, it had been earlier decided to establish a series of test installations at a number of sites used by the Bureau of Standards. Samples of Class 100 cast-iron pipe, in 3-ft lengths, 6 in. in diameter, were randomly selected from stock. The ends of each were closed by welding on thick plates, with the plate at one end tapped to receive a copper tube. These "bombs" were then buried in several of the more corrosive soils at the same depth as the test samples of the Bureau of Standards. The bombs were filled with water when installed and the copper tube brought to the surface (Fig. 6).

These bombs, in their undisturbed condition, were subjected to pressures of 400 psi, at intervals of approximately 2 years. This pressure is well in excess of normal operating pressures. After the bombs had been tested in this way for 12 years, none had failed, in spite of the fact that the cast-iron specimens of the Bureau of Standards had shown complete penetrations at one of these test sites and had almost been punctured at some of the others. The results of these tests are shown in Table 4.

TABLE 4

Performance of Test Bombs Installed at Various Sites*

Location of Bomb	Year Installed	Year Evaluated	Evaluation
Buttonwillow, Calif.	1928	1957	withstood 400 psi
Niland, Calif.	1928	1957	failed at bronze weld at 375 psi
Cholame Flats, Calif.	1940	1952	failed at bronze weld at 285 psi
New Orleans, La.	1928	1946	failed at 275 psi
San Antonio, Tex.	1928	1957	withstood 400 psi
San Antonio, Tex.	1928	1957	withstood 400 psi
San Antonio, Tex.	1928	1957	withstood 400 psi

* All test bombs were of 3-ft lengths of 6-in., Class 100 cast-iron pipe, except for one 1.5-ft length at San Antonio.

After the specimen at Niland, Calif., was removed, it was sandblasted. This revealed six graphitized areas going completely through the wall of the pipe; the largest hole formed was ¾ in. in diameter. In spite of this, the bomb failed at the bronze weld at the end of the specimen, not at the holes. This series of tests is still in progress.

As a result of its work on graphitized cast iron, the Bureau of Stand-

ards has concluded that "Cast-iron pipe in an advanced stage of graphitic corrosion is able to withstand the minimum pressure of Class 150 pipe." [5] It should be noted here that the soils used in the survey tests on graphitic corrosion are all of the most corrosive type used in the studies of the Bureau of Standards and do not reflect the usual effects of the vast majority of soils in the United States.

Summary

Three basic factors must be considered in evaluating the potential corrosion hazard to an underground piping system:

1. Are there any external sources of direct current that might enter the earth and thereby cause the pipe to become a part of the electrical circuit? Such sources as street railway systems, mining operations, cathodic protection installations on other structures, and improper use of welding equipment must be studied.

2. Is the environment itself in which the pipe will be installed aggressively corrosive? In other words, will the environment produce or tend to accelerate galvanic or bacterial corrosion?

3. What has been the history of corrosion on existing structures in the area?

With regard to the effects of soil, the results of many tests support the conclusion that cast-iron pipe has a long useful life, even in soils considered aggressively corrosive to ferrous metals. Cast-iron pipe has the advantage of being somewhat electrically discontinuous and thus less susceptible to becoming a long corrosion cell. Field studies of cast-iron pipe in water systems located at widely scattered points in the United States and in a variety of soils have shown that cast iron resists corrosive attack very well where stray current factors are not actively involved.

The data obtained by the Bureau of Standards clearly indicate that there is essentially no correlation between the rate of corrosion of cast-iron pipe and soil resistivity alone. The bomb tests of the Cast Iron Pipe Research Association have shown that cast-iron pipe in an advanced state of graphitic corrosion has sufficient strength to withstand pressures many times those required in normal service. This work has also been confirmed by the Bureau of Standards.

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Toxicity of Small Quantities of Cadmium and Chromium in Drinking Water Administered to Dogs During a 4-Year Period

Richard U. Byerrum, Rashid A. Anwar, and Carl A. Hoppert

A report prepared for Advisory Committee 2610 P—Chromium and Cadmium Solubility and Toxicity, and presented on Jul. 14, 1959, at the Annual Conference, San Francisco, Calif., by Richard U. Byerrum, Prof. of Chemistry; Rashid A. Anwar, Research Instructor in Chemistry; and Carl A. Hoppert, Prof. of Chemistry, all of Michigan State Univ., East Lansing, Mich.

PREVIOUS studies [1-3] at the authors' laboratory at Michigan State University have shown that 0.1–10 ppm of cadmium and 1–25 ppm of chromate in drinking water had no effect on the growth rate or food consumption of rats over a 1-year period. In addition, no pathologic changes in blood or other tissues were noted in these animals. Although these studies indicated that small concentrations of cadmium and chromate were nontoxic, the experiments were limited, for only one species of animal was used and the total period of consumption of the elements was 1 year. The present study was undertaken to ascertain the effect on dogs of small amounts of cadmium and chromate ions in drinking water administered over a 4-year period.

Cadmium Studies

Four pairs of female dogs were administered, ad libitum, drinking water containing 0.5, 2.5, 5, and 10 ppm of cadmium as cadmium chloride. A control dog received water with no cadmium added. All dogs were fed a commercial dog food that contained essentially no cadmium. Animals drinking water containing the above concentrations of cadmium showed no abnormalities in physical condition, food or water intake, or growth during a 4-year period. There was, however, an accumulation of cadmium in the liver and kidneys which was proportional to the concentration of the element in the drinking water, when the concentration of cadmium was 5 ppm or less. The pancreas showed a small increase in cadmium in proportion to the quantity in the drinking water, but the concentration (in parts per million per gram wet weight of tissue) was less than that in the liver or kidneys. The cadmium content in these three organs of dogs receiving 10 ppm of cadmium was essentially the same as that in the tissues of dogs receiving 5 ppm of cadmium. Routine examination of urine for albumin and of blood for total hemoglobin, red cells, and white cells showed no abnormalities. Microscopic examination of tissue sections from all the test animals is in progress.

An attempt was made to isolate a cadmium-protein fraction from dog liver [4] after a single nontoxic dose of Cd^{115}, in the hope that a naturally occurring, cadmium-containing protein might be discovered. Margoshes and

Vallee [5] have reported the possibility of a cadmium-protein in horse kidney. Previous work at the university laboratory [6] showed that a few hours after a rat was given a single intravenous injection of Cd^{115} $(NO_3)_2$, about 65 per cent of the injected dose appeared in the liver. This concentration of radioactive cadmium remained essentially constant over a 5-week period.

The protein precipitates obtained when a water extract of an acetone powder of dog liver was made 10 per cent with trichloroacetic acid (TCA) showed no radioactivity, although 70–75 per cent of the total radioactivity of the liver acetone powder was found to be soluble in water. About 90 per cent of the radioactivity extractable with water was nondialyzable, but when ammonium sulfate was used as a precipitating agent, the protein precipitates were found to contain much of the radioactivity. This observation suggests a loose binding of cadmium with the proteins. Margoshes and Vallee [5] have also observed that cadmium was removed from the cadmium-containing protein fraction isolated from horse kidney on treatment with warm TCA.

Inasmuch as no cadmium could be detected in the liver or kidneys of control dogs that received no added cadmium in water, and because of a loose attachment of cadmium to the liver protein fractions, the binding of cadmium in the liver and kidneys may be a part of a detoxication mechanism. Cadmium may be preferentially bound to certain proteins, so that it may not inactivate certain cadmium-sensitive enzymes.

Chromium Studies

For 4 years, five pairs of female dogs were administered, ad libitum, drinking water containing 1.0, 5, 10, 15, and 25 ppm of chromate ion as potassium chromate. The commercial dog food used contained a small quantity of chromium. No abnormalities in food or water consumption, general appearance, or growth rate could be noted in any of the animals, nor were there any differences between the control and experimental animals as regards hemoglobin concentration, red cell count, or white cell count. There was an accumulation of chromate in the liver of all animals receiving chromate in the drinking water. This accumulation was greater than that observed in rats in a similar experiment.[3] An abrupt increase in chromate concentration in liver tissue was noted in the dogs receiving concentrations of chromate greater than 15 ppm. In contrast with previous observations in rats, chromate concentrations in dog spleen were found to be less than those in liver. Microscopic examination of various tissues from these animals and studies of the effect of chromate on liver enzymes are in progress.

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Experiences in the Use of Porous-Plate Filter Bottoms

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A paper presented on Oct. 28, 1959, at the West Virginia Section Meeting, Parkersburg, W.Va., by Frank C. Roe, Supervising Engr., Sales Eng. Dept., The Carborundum Co., Perth Amboy, N.J.

DURING the past 20 years, most water utility men have heard or read something about porous-plate filter underdrains and know that the use of such construction has been extensive. Progress in its use has been based on the benefits derived through elimination of graded gravel as a filter medium support, the chief benefit being that porous-plate filter bottoms make it impossible for a bed to be upset.

A good share of the literature on the subject, including some articles by the author, discusses the origin, history, and advantages of porous-plate filter bottoms in considerable detail. Some of the more interesting papers have been those that covered actual operation experiences. Specifically, reports have appeared on performance at Denver; Larchmont, N.Y.; Flat Rock, Mich.; Fort Smith, Ark.; Lewiston, Idaho; and Washington, D.C.

Early Development

The first experimental studies, which grew out of the natural desire to eliminate graded gravel for filter medium support, took two courses. The first material tried was the smallest size of the usual supporting gravel, bonded with portland cement to form a porous slab. This proved unsuccessful in a comparatively short time, because the meager, semisoluble cement bond was completely inadequate to hold the gravel granules together.

The basic idea persisted, however, until tests were made of ceramically bonded porous plates. It was believed, as has now been proved, that a glassy bond fired in a high-temperature kiln is both strong enough mechanically and sufficiently insoluble to provide permanent construction. Two independent tests were made of ceramically bonded plates, the first at the University of Texas and the second at Providence, R.I. These were made, respectively, with silicate-bonded silica granules and clay-bonded, fused aluminum oxide granules.

The granules of these materials were relatively small compared with the pea gravel previously tried. The test plates were of the grade then used for air diffusion of small bubbles into sewage, and *the available pore opening was considerably smaller than the interstices between ordinary sand particles.*

The Texas experiment proved that the basic idea was mechanically sound, but the raw water was not treated before filtration, and it was not possible to establish overall performance over a period of time. In contrast, the Providence experiment paralleled operation in the city's water treatment plant. As might have been expected, the underdrain plates eventually became clogged

by the small solids that were able to pass through the filter medium.

This is where the author's firm came into the picture. It was recognized that it was necessary to support filter media on a material *with pore spaces larger than the interstices between the filter sand or anthracite granules.* Selected granules of 6–10 mesh, fused aluminum oxide were used to produce the very first underdrain plates, and that composition has remained in use to date. Thus, it can confidently be said that porous-plate filter bottoms will not clog if the selection is correct in the first place, and if the treatment plant is operated normally. Any trace solids that do find their way through the filter medium readily pass through the larger pores of the underdrain plates.

There are a few special situations that can result in clogging, but the explanations are just about as simple and obvious as was the need for selecting coarse size granules for plates. These exceptions are described below.

Clogging Difficulties

Perhaps the first question asked by anyone not acquainted with the use of porous-plate filter bottoms is whether they will clog. This is a reasonable question, in that certain porous media used for direct filtration do clog and porous diffusers used for aerating sewage have some history of clogging, but there is no real physical similarity between these applications and filtration of water supplies. Nevertheless, the author knows of one prominent consulting engineer who will not consider porous filter bottoms for filtration plants, because porous air diffusers have been known to clog under some conditions in sewage treatment plants. Porous-plate filter bottoms do not clog under normal and proper conditions of plant operation and if they are properly designed. They can clog if there is a misapplication or if subnormal operation occurs. Thus the experiences at various installations are significant, because they help to establish criteria of what to do and what not to do.

Raw-Water Problems

If the water supply to be filtered undergoes no pretreatment and has high seasonal turbidity, it is probable that the quantity and nature of solids passing through the filter bed will, in time, cause an accumulation in the fixed angular and irregular pores of standard porous underdrain plates. Such an accumulation may increase pressure loss to an objectionable degree, although it will seldom, if ever, progress to the degree that adequate backwashing with filtered water will not maintain operation.

The author knows of two specific instances of interception of solids that could not be completely filtered from untreated raw water. Both installations were in paper mills, where the estimated cost of constructing and operating adequate pretreatment facilities exceeded the cost of underdrain plate cleaning and replacement, if and when necessary.

Probably there are other instances of this condition, because many pressure and gravity filters equipped with porous filter bottoms are used to filter water for swimming pools. It is likely that in most such installations a condition of equilibrium is developed by backwashing with relatively clean pool water, thus keeping the underdrain plates clear enough to prevent increased pressure loss.

Alum Difficulties

If a water supply is treated with alum to coagulate solids and insufficient time or other difficulties prevent completion of such pretreatment, afterprecipitation of alum can cause an accumulation or coating within the underdrain plate pores. Again, good backwashing with clear water can help to establish a condition of equilibrium, but pressure loss through plates may be high.

There has been some definite experience with alum clogging. As a matter of fact, the first operating filter using coarse-grade underdrain plates, installed at Chicago's experimental plant in 1935, encountered this difficulty. It was found, however, that the plates responded readily to overnight treatment with sodium hydroxide, without necessitating removal of the filter medium.

A somewhat similar experience was reported at the earliest municipal installation made by Denver, in 1936. The elimination of alum clogging by sodium hydroxide treatment was very effective and economical in comparison with the operation of the previous graded-gravel underdrain system.

A few parallel experiences with alum clogging were recorded or reported during the following 20 years. There is no current record of such experiences, however, because no plates have been removed for replacement. In other words, alum clogging, even though it may develop, has not been the source of enough trouble to render the porous-plate system impractical.

Hydroxide Problems

A more likely form of plate clogging is found in plants built for removal of iron or manganese. After the water is aerated to form insoluble hydroxides, there should be an adequate period for coagulation and settling (possibly supplemented with sodium phosphate treatment), before final and complete removal by filtration is attempted. Otherwise, a coating of hydroxides will form within the porous structure of underdrain plates. If this condition develops in a comparatively short period of time, operation becomes unsatisfactory, because acid treatment to remove iron and manganese from porous plates is somewhat complicated and expensive.

The consequences of iron and manganese clogging are quite serious. One installation, made in the late 1930's at Dakota City, Neb., was removed and replaced by another type of filter bottom. This small municipal plant was operated by the town marshal. Clogging was so serious that it could not have been controlled without constructing a new treatment plant, which the town certainly could not afford. Dakota City is the only instance of serious clogging, but there probably have been a few similar but less critical experiences. Porous plates have been installed in several iron removal plants, but there are no other recorded instances of removal or replacement.

Calcium Carbonate Deposits

The next, and potentially most serious, condition that can cause clogging exists where a hard water is treated with lime and the reaction is incomplete when the water is discharged onto the filters. The resulting incrustation of calcium carbonate on filter media may extend to the filter bottom and on through the system. It is, in fact, planned that way in some systems as a means of protection against water that may be too soft or

otherwise aggressive. The coating or plugging of pores with calcium carbonate is probably not a condition that can be slowed down to equilibrium by backwashing. It is more likely to progress until the pores are almost completely filled, so that only acid treatment can restore an open structure.

In a new installation made at Elgin, Ill., in 1937, pretreatment was so incomplete that considerable lime was noted even on top of the filter beds during the filtration part of the cycle. Coating of the underdrain plates was noted within a matter of days. For many reasons, it was considered that adequate pretreatment could not be installed and the porous underdrain plates were removed. The plates were returned to the author's firm, given an acid soak, refired, and put in stock for later use under more suitable conditions.

With a full-size, reconstructed filter at Flint, Mich., carbonate incrustation was expected because it was known to exist through and beyond the filters, but the local manager still preferred to eliminate gravel support and wanted to establish the time before clogging of plates became serious. The time was too short. Within a year, serious increases in pressure loss occurred, to the extent that the filter broke down completely during backwash. The Flint experience illustrated the adequacy of plate strength and of the corner-bolting method of installation, the plates did not break under the high pressure differential during backwash, although they were almost completely plugged with calcium carbonate. The concrete piers to which they were bolted were actually lifted out of position.

Somewhat similar experiences of calcium carbonate clogging were recorded in a few other places. At the same time, reports were being received on softening installations in which plate clogging did not develop to a serious degree.

Raw-Water Backwash

One other practice that is known to cause clogging of standard-grade underdrain plates is the use of raw water for backwashing filters. This is such a subnormal practice that it should not have to be mentioned. Obviously, there is nothing whatever to prevent the suspended solids in raw backwash water from accumulating in the pores of underdrain plates. Because the solids are lodged at a high upward velocity, the relatively slow downward velocity during the filtration part of the cycle cannot flush them out. Of course, this practice is unthinkable in connection with a public water supply, but it is surprisingly common for industrial supplies.

The only known instance of serious plate clogging due to the use of raw water for backwashing was at a paper mill in Canada. Clogging became serious during spring floods, and, because the plates could not be cleaned in any practical manner, they had to be removed and another system installed.

Design and Installation Developments

Over a period of 25 years of developing any idea, it can be expected that several features of design will be proved unsatisfactory and new successful features will be found. It was learned within only a few years, for example, that porous plates with wash water laterals formed in them could not be successfully cemented to a filter floor and that such plates were too expensive

when bolted down. Thinner plain plates, supported and anchored essentially as a false bottom by several different methods, proved to be the only practical basic design.

The question of how best to seal joints between plates has arisen throughout the development period. Almost any type of insoluble but strongly adhesive cement, which will not impart taste or otherwise contaminate a supply, can be used satisfactorily. It is frequently difficult, however, to obtain workmen who are sufficiently conscientious to do a good job of installation. There is nothing difficult about preparing a cement that can be "buttered" on the edge of plates to provide a satisfactory seal, but the workmen must do it carefully and not miss any joints in the process.

Within the last few years, gaskets have been developed to seal the joints between porous-plate underdrains. These have proved completely successful as well as economical.

The first gasket was a rubber H section. Strips of this material, installed so that the open ends would engage each plate, proved very satisfactory. Unfortunately, the gasket manufacturer has shown no further interest.

In the meantime, a flexible polyvinyl chloride gasket has been developed and is working out excellently. This is a wide, continuous, corrugated band which exactly fits around the edge of each standard plate before it is installed in position. Thus, if every plate is so gasketed, there are two thicknesses of this material in each joint.

Bolts, nuts, and washers to anchor or support plates have not created any problems through the developmental years, but a definite trend toward the use of stainless steel has become established. No real trouble was ever experienced with well galvanized or sherardized steel bolts, but, as the cost of stainless steel decreased, its use became more or less universal for underdrain plates. As the labor cost of installing bolts has increased, this trend to stainless-steel bolts was encouraged.

Current Practice

By 1948 experiences with porous-plate filter bottoms had established reasonably clear areas of proper application and satisfactory design. There are now approximately 500 installations, and the number of misapplications that create clogging or installation difficulties is becoming very small.

Publicity, correspondence, and contacts have been responsible for this satisfactory development and prevention of trouble. In Sioux Falls, S.D., for example, both the local utility manager and the consulting engineers wanted to build a new softening plant equipped with porous-plate filter bottoms. The possibility of difficulty with carbonate incrustation was clearly outlined to all parties involved. They still wanted to use porous plates in order to eliminate the difficulties they had experienced with graded gravel and went ahead with the project, making certain, however, that the water delivered to filters would always be stable. The plant was built in 1954, and there has been no increase of pressure drop through the filter bottom to date.

Another interesting phase of current practice to determine economical filter design for future use in large cities, has been the full-scale operation of porous plate–equipped filters. In each instance one or more of the other current types of filter bottoms have been installed

simultaneously so that performance could be compared concurrently and under similar operating conditions.

Among the old large municipal plants in which new porous filter bottoms have been installed are those in Washington, D.C. and Philadelphia. New plants having one unit equipped with porous plates are at Houston and Denver.

Costs

The cost of porous-plate filter bottoms depends largely on local conditions, basic design features, and whether plates are installed for reconstruction of old filters or as a part of a new filtration plant. Of lesser but still considerable consequence are the kind of accessory materials, ability of workmen, geographic location and, of course, the total area to be equipped.

The 1959 delivered cost of plates alone varies from $4.32 to $4.85 per square foot, depending on quality. Stainless-steel bolts, nuts, and washers normally run about $1 each but may cost up to 50 per cent more. The new polyvinyl chloride gaskets are about 50 cents each. The material cost therefore ranges from approximately $6 to $7 per square foot.

Reported figures on the cost of installation have varied greatly during the period of the author's experience. It is doubtful, however, if reliable cost data have been reported on more than 5 per cent of the installations. The rule of thumb that the author's firm has used in providing engineers with a rough estimate to cover labor of installing has been $4.50–5.00 per square foot.

Need for Unified Designs

One point that has been forcibly brought out as a result of experiences during the years of development is the need for unified filter bottom designs that can be purchased complete. For the most part, engineers and utility managers have had to put the bits and pieces together with the help of a set of specifications. This requires time and effort and divides responsibility. There is a natural tendency to avoid such practice and choose another design, even though the alternative is less desirable. The development and sale of porous-plate filter-bottoms have thus been handicapped.

Porous-plate filter bottoms have nevertheless become an integral part of some excellent complete filter units. One manufacturer offers a unique automatic-backwash filter. It has a background of proved performance in a number of installations over the past 15 years.

Two or three companies now offer pressure filter units equipped with porous-plate underdrains. The economic advantage of reducing the size of such units as a result of eliminating the use of graded gravel, is obvious.

It is to be expected that equipment manufacturers will take more and more advantage of the economic and functional benefits offered by porous-plate underdrains as a basis for developing a so-called filter bottom package that will be adapted to the usual gravity filter designs. From a practical, long-range economic viewpoint, this trend is bound to be beneficial to engineers, utility managers, and others responsible for water filtration.

Conclusion

The many benefits to be derived from the use of porous-plate filter bottoms for normal situations far outweigh the limitations, which exist only in unusual or subnormal situations.

The course of development of porous-plate filter bottoms illustrates a sound principle: a fundamentally poor idea or piece of equipment will utimately fall by the wayside, no matter how much publicity or effort is expended to promote it. By the same token, an idea, material, or piece of equipment that offers a fundamental economic benefit is bound to retain interest and gain ultimate acceptance.

Generally speaking, it has been easy to interest operators and managers in the natural benefits of porous-plate filter bottoms but often difficult to establish acceptance among consulting engineers. The reason for this difference in reaction is no mystery. Generally, the former have had a long operating experience with filters using graded-gravel underdrains, whereas the latter sometimes have little or no plant operating experience. This is intended as an observation and not a criticism.

Experience has thus been the key factor in the entire background of rapid sand filtration. Difficulties experienced with gravel led to the original conception of the rigid porous-plate underdrain system and have maintained interest in the current type of porous underdrain system ever since the first trial installation at Chicago in 1934.

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Taste Threshold Concentrations of Metals in Drinking Water

Jesse M. Cohen, L. J. Kamphake, E. K. Harris, and Richard L. Woodward

A contribution to the Journal by Jesse M. Cohen and L. J. Kamphake, chemists; E. K. Harris, Chief, Statistical Services; and Richard L. Woodward, Chief, Eng. Section; all of the Water Supply & Pollution Branch, Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.

THE USPHS *Drinking Water Standards* of 1946 [1] are currently being re-examined in preparation for revision incorporating new knowledge acquired in the subsequent years. In establishing limits on concentrations of certain metals in drinking water, one of the several factors that must be considered is taste threshold. The technical literature is, unfortunately, lacking in such data. The study reported here was undertaken to provide taste threshold data on copper, iron, manganese, and zinc for consideration in the revised standard. The results of the study are summarized in Table 1, in which 5 per cent and 50 per cent points on the cumulative frequency distributions of taste threshold concentrations are shown for each metal.

Earlier Investigations

During the years 1918–19, Stoof [2] conducted a series of taste experiments with tap water. He concluded that: (1) the limits of perception are lowest for ferrous iron and highest for potassium salts; (2) the anions can be arranged in order of increasing taste threshold as OH^-, NO^-, Cl^-, HCO_3^-, SO_4^{--}; (3) the cations can be arranged in order of increasing taste threshold as Na^+, Mg^+, Ca^{++}, Fe^{++}, Mn^{++}; and (4) ammonium ion is characterized in all its salts by a low threshold, and potassium hydroxide, in contrast to its salts, is easier to recognize than sodium hydroxide.

In the early 1900's, experimental work was undertaken to examine the physiological effects of lead, galvanized iron, copper, and brass metals which were used extensively for water storage and conveyance. During this period little or no mention was made of the effects of these metals on the taste of water. One of the earliest recorded references to objectionable metallic taste in a public water supply was made by Scott and Jameson,[3] who reported that water stored in a galvanized-iron tank had a definite metallic taste and was shown to contain not less than 47.2 ppm of zinc.

Copper. The flurry of research during and following the acceptance of copper and copper alloys as piping materials produced a large amount of data on the solubility and physiological effects of these metals, but relatively little on the resulting taste of the water. Schneider [4] quotes the Prussian Hygienic Institute for Water, Soil, and Air in Berlin, which stated that it was possible that a copper concentration of 3–5 ppm could affect the taste of water adversely. Schneider suggested a few years later [5] that the ad-

missible amount of copper in water be set at 5 ppm, as a greater content would give the water a disagreeable taste. Spitta,[6] critically reviewing the literature on the effect of copper on human health, stated that 2 ppm of copper was the taste threshold concentration. Froboese,[7] on the other hand, reported that 1.5 ppm was the lowest concentration of copper that normally could be tasted.

Zinc. The extensive use of galvanized-iron pipe prompted comprehensive investigations into the health effects of dissolved zinc. In an excellent summary of the literature, Drinker and Fairhall [8] reported that a panel of ten men and ten women judged the taste of zinc sulfate in distilled water, with these results: 2 detected the taste at 19 ppm, 4 at 37 ppm, 10 at 73 ppm, and the remaining 4 at 156 ppm. The taste was described as unpleasant and astringent. Bartow and Weigle [9] reported that water supplies in Brisbane, Australia, containing 17.1 ppm of zinc and West Berlin, Mass., containing 18.5 ppm produced no unpleasant results. Mason [10] reported no ill effects from the constant use of water containing 23 ppm of zinc. In a survey on the occurrences of high concentrations of zinc in drinking water, Anderson, Reinhard, and Hammel [11] stated that 40 ppm of zinc gives water a milky appearance and produces an astringent taste. In a review of all aspects of zinc in drinking water, Hegstedt, McKibben, and Drinker [12] concluded that 30–40 ppm of zinc is reasonable and safe in drinking water. The implication is that the taste is not objectionable at these maximum levels.

TABLE 1

Taste Thresholds for Metals in Water

Metallic Constituent*	Threshold Frequency in Distilled Water		Threshold Frequency in Spring Water	
	5%	50%	5%	50%
	Ion Concentration—*ppm*			
Zinc sulfate	4.3	18	6.8	27
Zinc nitrate	5.2	22		
Zinc chloride	6.3	25	8.6	33
Cupric chloride	2.6	6.6	5.0	13
Ferrous sulfate	0.04	3.4	0.12	1.8
Hydrous ferric oxide	0.7	8.8		
Manganous sulfate	3.6	45		

* Threshold values are for the metal ion, not the salt.

Iron. Although it is common knowledge that iron imparts a metallic taste to water even when present in low concentrations, there appears to be little quantitative data in the literature. A notable exception is the work of Balavoine [13] who determined the taste threshold concentrations of certain metals in various substrates, including distilled water, as: copper, 2 ppm; ferric iron, 0.2 ppm; ferrous iron, 0.1 ppm; and zinc, 2 ppm. He also pointed out that ferrous iron imparts a more noticeable taste than does ferric iron. Using the triangle method of

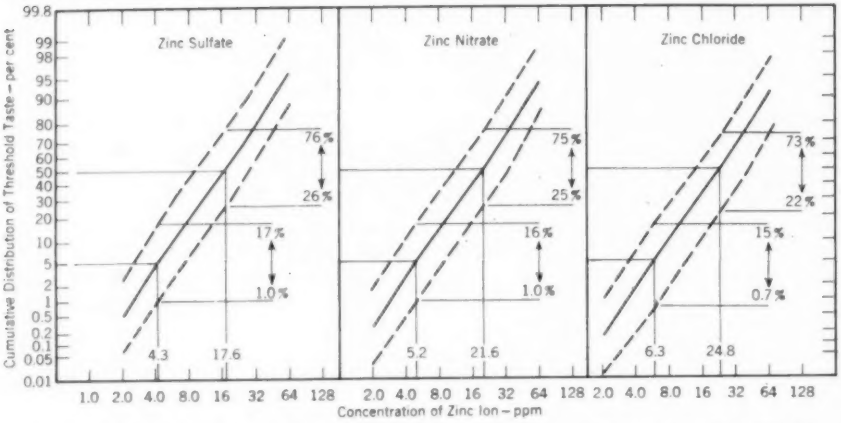

Fig. 1. Distribution of Taste Threshold Concentrations of Zinc in Distilled Water

Shown are estimated taste thresholds for 50 per cent of the panelists and the most sensitive 5 per cent. The dashed lines represent the 95 per cent confidence limits.

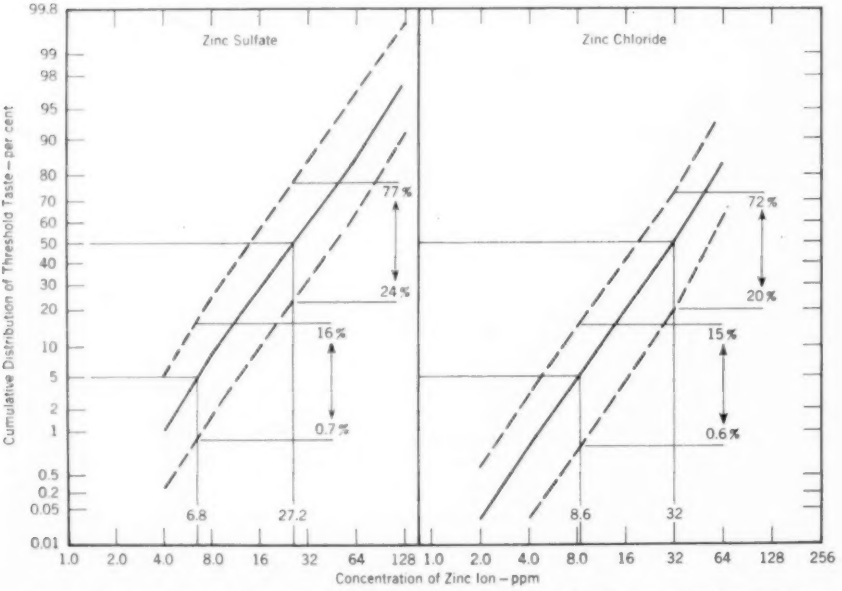

Fig. 2. Distribution of Taste Threshold Concentrations of Zinc in a Spring Water

Shown are estimated taste thresholds for 50 per cent of the panelists and the most sensitive 5 per cent. The dashed lines represent the 95 per cent confidence limits.

testing and a panel of 18 or more members, Lockhart, Tucker, and Merritt [14] found 10 ppm to be the taste threshold for ferric iron added to distilled water as ferric sulfate (this was the only reference that described the method of determination).

Test Water

Both distilled water and spring water were used for test solutions to determine whether mineralization affects threshold determinations:

1. Distilled water was treated with a large excess of activated carbon to remove all extraneous taste. Following addition of metal salt, adjustment of pH was made with either sodium bicarbonate solution or gaseous carbon dioxide to yield a final pH of 6.0–6.5.

2. Natural spring water was treated with 1.0 ppm chlorine, usually overnight, and then dechlorinated with activated carbon. Initial adjustment to pH 6.5 was obtained by adding 1.0*N* sulfuric acid; final pH control, after addition of metal salts, was accomplished in the same manner as for distilled water. In some tests an excess of carbon dioxide was added to obtain a lower pH in order to keep some of the metals in solution. Analysis of the spring water after chlorination, dechlorination, and pH adjustment to 6.5 is shown in Table 2.

General Procedure

In all of the tests, a stock solution was prepared by dissolving the analytical grade metal salt in the test water. Computed aliquots of the stock metal solution were added to the test water and the pH was adjusted to 6.0–6.5. In some cases desired solubility was obtained by adding carbon dioxide to lower the pH. If the lower oxidation state of the metal was desired, as, for example, with ferrous iron, oxygen was removed by bubbling nitrogen through the test solution for several hours, and transfers of solution were made by siphon to avoid reaeration with atmospheric oxygen. Final concentrations of metal in solution were checked by quantitative determinations for the specific metal.

Judges were presented portions of the metal solutions in 50-ml beakers. Dark brown, 2-oz bottles were used for those tests which involved colored solution in the higher concentrations.

Taste, unfortunately, can be measured only the subjective judgment of the individual. A degree of objectivity can be attained by use of tests which depend solely upon discrimination. For this reason two experimental methods were selected for the determination of sensory differences. The panel was composed of 15–20 judges selected from the laboratory staff, many of them accustomed to evaluating water quality by taste or odor. Some were smokers; others were not. At first, a modification of the "triangle test," a phrase used by Helm and Trolle,[15] was used in all of the testing. This method was supplanted by the duo-trio test,[16] which provided the data with less fatigue.

TABLE 2

Mineral Analysis of Adjusted Spring Water

Constituent	Concentration *ppm*
Alkalinity (as $CaCO_3$)	207
Hardness (as $CaCO_3$)	354
Calcium	96
Magnesium	26
Chloride	14
Sulfate	132
Total solids	460
Iron	<0.01
Copper	<0.02
Zinc	<0.01
Manganese	<0.05

Modified Triangle Test

In the triangle test, the test solutions were presented to the panel members in sets of three of the type AAB. In this test, the taster was served three samples identified only by a code number and was aware that two of the samples were identical. Each set of three consisted either of one sample of plain test water and two of test water containing a metal salt, or one sample of the metal salt solution and two of the plain water. Combinations were presented randomly in the six possible orders (AAB, ABA, BAA, BAB, ABB, and BBA), each at a different concentration. Plain test water was used as a rinse between each sample. In each set, the panelists were asked to select the odd sample.

In this modification of the standard triangle test, the panelists were further required to state whether the samples were plain test water or metal salt solution. In each test period they were presented with three sets of triangles, each set representing an increasing concentration of the metal salt. The following day three additional sets of triangles were offered, to yield a total of six concentrations.

Duo-Trio Test

In the duo-trio test, samples were offered to the judges in pairs rather than in sets of three. Each judge was provided with uncontaminated test water which served both as a rinse and a control. He was then given, in unknown order, a pair of samples, one of which was pure water and the other test water containing a concentration of metal salt. The judge was required to state which beaker in the pair contained the metal salt solution. In all cases a judgment was forced even though no discrimination could be made. In each test period a series of 5–7 pairs, covering the range of metal salt concentrations, were judged by each panel member.

TABLE 3

Taste Threshold Frequencies at Varying Concentrations of Zinc Ion

Zinc Ion Concentration *ppm*	Distilled Water			Spring Water	
	Cumulative Threshold Distribution—%				
	Zinc Sulfate	Zinc Nitrate	Zinc Chloride	Zinc Sulfate	Zinc Chloride
2	0.5	0.2	0.1	0.07	0.03
4	4.8	2.8	1.9	1	0.06
8	21	14	10	8	4.5
16	47	38	32	29	19
32	78	71	64	59	50
64	96	94	91	64	84

Computations

Results of these threshold experiments were analyzed statistically to estimate the proportion of individuals able to discriminate between the test material and the solvent at or below each concentration. An individual's threshold was defined to be a concentration such that, at all equal or higher concentrations, the individual was certain to identify the test samples cor-

rectly, whereas at lower concentrations he would do so purely by chance.

Actually, an individual's threshold was allowed a range between two adjacent concentrations, as the cumulative proportion of thresholds was estimated only at those concentrations used in the experiment. The probability, p, of correct identification by chance below the threshold was determined by the design of the test; for example, $p=\frac{1}{3}$ in the modified triangular test and $\frac{1}{2}$ in the duo-trio test. Mathematical details of the statistical methods have been published by Harris.[17] In addition to estimating the cumulative frequency distribution of threshold concentrations, 95 per cent confidence limits for the true distribution for each compound were also computed. These limits take into account the variations in estimated threshold distributions that would be possible if the same panel were given the same tests repeatedly. Proper interpretation of such limits is given in the results reported below.

Zinc

Zinc sulfate, zinc chloride, and zinc nitrate were tested in both distilled and spring waters by the modified triangle method. The three anions were selected to determine the effect of each on the taste threshold of the metal cation. Adjustment of the hard spring water to a pH of 6.0–6.5 permitted testing at concentrations up to 128 ppm without serious problems of precipitation. Concentrations of dissolved zinc were determined by the dithizone mixed-color method as described in *Standard Methods*.[18]

The data for zinc salts in distilled water are presented in Fig. 1, in which the cumulative threshold distribution is plotted as a solid line against ion concentration. The two dashed lines represent 95 per cent confidence limits. Also shown are the threshold concentrations of 50 and 5 per cent of the panel. At each of these levels, the computed 95 per cent confidence limits are shown. For example, in the case of zinc sulfate in distilled water, the estimated taste threshold of 50 per cent of the panel, based on a single test series, was 17.6 ppm of zinc. It is, however, 95 per cent certain that if thresholds were determined repeatedly by the same panel, the average proportion of individuals detecting a taste at 17.6 ppm or less would be greater than 26 per cent but less than 76 per cent. The more sensitive 5 per cent of the panel were able to detect zinc sulfate at a concentration of 4.3 ppm as zinc ion. The 95 per cent confidence limits for the true average portion of the panel detecting this concentration are 1.0 and 17 per cent. The data show that the 50 per cent taste threshold for zinc ion increases according to the compound added, in the following order: 17.6 ppm $ZnSO_4$, 21.6 ppm $Zn(NO_3)_2$, 24.8 ppm $ZnCl_2$ as Zn.

The taste of zinc was less noticeable when mineralized natural spring water was used as the solvent. The test data are presented in Fig. 2. The taste threshold for 50 per cent of the panel was 27.2 and 32 ppm of zinc as zinc sulfate and zinc chloride respectively.

The threshold frequencies for various concentrations of zinc ion are summarized in Table 3. Concentrations of zinc of the order of 2 ppm were detected by less than 1 per cent of the panel. At 4 ppm, zinc was readily detected in distilled water by a significant percentage of the panel, although a natural water had suppressed the taste for all except the more sensitive 1 per cent. Zinc at 8 ppm produced a taste in a natural water for 4.5–8 per cent of the panel.

The taste of zinc was generally described as astringent or bitter, with considerable persistence of taste and astringent sensation even after rinsing; this may have influenced the accuracy of the judgment. The effects of the carryover probably were reduced by presenting the subsequent samples in increasing concentrations, so that judging always proceeded from a lesser to higher concentration.

Copper

The familiar compounds of copper are derived from both the +1 and +2 oxidation states of the metal. As the cuprous forms are unstable in water, only cupric chloride was tasted in both distilled and spring waters using the modified triangle method. To prevent precipitation of copper carbonate in the hard spring water, up to 200 ppm of carbon dioxide was added, although the pH was maintained at 6.5. The same amount of carbon dioxide was added to the blank and rinse waters. Most of the judges were aware of the excessive amounts of carbon dioxide, but, as both the blank and metal salt solutions contained the same amount of carbonation, and as the judges were required to detect only a difference, it is unlikely that the taste threshold for copper was altered significantly by this procedure. Determinations of soluble copper were made according to cuprethol method described in *Standard Methods*.[18]

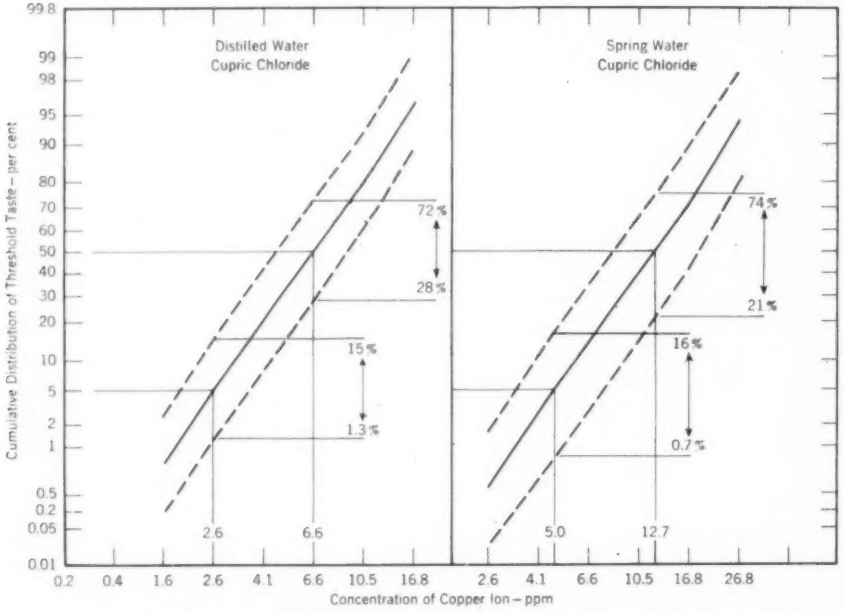

Fig. 3. Distribution of Taste Threshold Concentrations of Copper in Distilled and Spring Water

Shown are estimated taste thresholds for 50 per cent of the panelists and the most sensitive 5 per cent. The dashed lines represent the 95 per cent confidence limits.

Distributions of taste threshold concentrations for copper are shown in Fig. 3. Half of the panel detected the taste of 6.6 ppm copper added as cupric chloride in distilled water. A higher concentration, 12.7 ppm, was required in spring water before the same percentage of the panel detected a taste. At a concentration of 2.6 ppm in distilled water and 5.0 ppm in spring water, the taste of copper was apparent to 5 per cent of the panel.

The taste of copper was generally described as bitter. Some panel members noted a sweet sensation during smoking after the test.

Iron

Soluble iron occurs in natural waters predominantly in its bivalent compounds. Except for highly acid waters, the trivalent form of iron occurs as particulate matter ranging in size from readily settleable to colloidal forms. Iron also may be present in organic compounds.

No taste determinations were made on ferric salts because of rapid hydrolysis and precipitation even under acid conditions. As taste is produced only by materials in solution, it is likely that the insoluble ferric forms of iron would not adversely affect the taste of water; however, some estimation of the taste threshold of ferric iron was obtained by testing a colloidal suspension of hydrated ferric oxide, prepared according to a method described by King.[19] Attempts to prepare a soluble lignate and tannate of ferric iron proved unsuccessful; hence no estimate was made on these organic iron compounds.

Taste thresholds of ferrous sulfate were determined in both distilled and spring water solutions using both the modified triangle and the duo-trio methods. Oxidation and precipitation of the reduced form of the iron salt were minimized by lowering the pH of the test solutions to 5.0 and by reducing the dissolved oxygen to low concentrations (<0.2 ppm) with nitrogen gas. Analyses for the ferrous ion by the tripyridyl procedure described in *Standard Methods*[18] showed that only minor amounts (1–4 per cent) of the ferrous iron had been oxidized to the ferric state during the testing period. Dark-brown containers effectively masked the color of the water containing higher concentrations of colloidal ferric oxide.

Data obtained on iron, Fig. 4, show that 50 per cent of the panel were able to detect ferrous iron at 3.4 and 1.8 ppm in distilled and spring water respectively. These threshold concentrations are lower than any of the metals tested in the study. More significant, however, is the low concentration (0.04 ppm in the distilled water), at which the most sensitive 5 per cent of the panel could detect ferrous iron. A somewhat higher threshold (0.12 ppm) was obtained in the spring water. The least sensitive 5 per cent of the panel, on the other hand, was unable to detect iron at a concentration of 256 ppm in distilled water. Thus the taste of ferrous iron is characterized by a wide range of detectability. The most acute tasters were 6,400 times as sensitive as the least acute panelists.

Although not in true solution, colloidal hydrated ferric oxide was still capable of eliciting a taste response from the panel members. The thresholds were generally higher than for the soluble ferrous form of iron, however. The curve for this form of iron (Fig. 4) indicates that 50 per cent of the panel detected the taste of the metal at a concentration of 8.8 ppm; and the most sensitive 5 per cent had their threshold at 0.7 ppm.

The taste of iron was variously described as bitter, sweet, astringent, and "iron tasting."

Manganese

Although manganese exhibits oxidation states of +1 to +7, its only compounds of interest in natural waters are the manganous forms. All other inorganic forms either are unstable in water or form extremely insoluble oxides. Manganous sulfate was tested in both distilled and spring water using the duo-trio method. Determinations for manganese were made according to *Standard Methods*,[18] by the periodate procedure.

Stable manganous sulfate solutions were prepared by dissolving the salt in the test solutions and adjusting the pH to 6.4. No detectable oxidation occurred during the period of taste testing. From the data shown in Table 4, manganese did not produce a detectable taste in the spring water until present in relatively high concentrations. Only 1 per cent of the panel could taste manganese at a concentration of 32 ppm. By extrapolating on the threshold frequency curve, one may estimate the concentration at which 50 per cent of the panel would detect manganese as 180 ppm. Apparently manganese is more readily detected by taste in distilled water, as shown in Table 4.

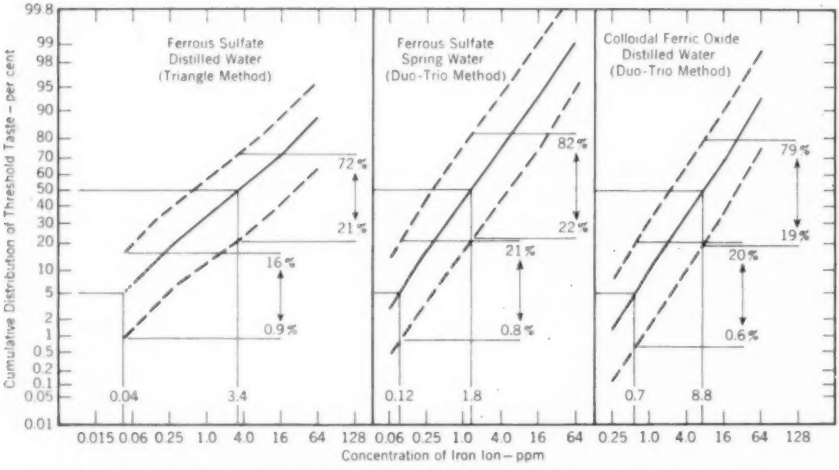

Fig. 4. Distribution of Taste Threshold Concentrations of Iron in Distilled and Spring Water

Shown are estimated taste thresholds for 50 per cent of the panelists and the most sensitive 5 per cent. The dashed lines represent the 95 per cent confidence limits.

Summary and Conclusions

Taste threshold frequency distributions have been determined for certain metals that frequently occur in natural waters and impart a taste to water in concentrations below those at which toxic symptoms are produced. These data may be of use in establishing limits for these metals in drinking water.

Application of laboratory panel data to the general population is difficult; it has been accomplished in the food products fields only at great expense

by large-population sampling. It is very likely that the thresholds obtained in this study are lower than those of the general public, for the panel members were accustomed to evaluating water for taste and odor. Some evidence was obtained that certain panel members, accustomed to drinking water containing substantial amounts of iron, were the least sensitive to iron in these tests. This may explain the wide range in detection of iron concentrations. Because of the limitations of panel composition and bias, no attempt was made to determine the relative acceptability of the test samples. Certain general conclusions can be drawn from the data summarized in Table 5, however.

Zinc was detected at the 5 per cent frequency level at a concentration of 4.3 ppm. The taste was generally characterized as bitter, but it was detectable also by the astringent sensation which persisted for some time after tasting. At the 5 per cent frequency level, copper behaved similarly to zinc and was detectable at a concentration of 2.6 ppm. The taste of copper was persistent and was particularly noticeable as a sweet sensation during smoking following the testing period. Ferrous iron was detectable at the lowest concentration of the metals studied, being readily tasted by 5 per cent of the panel at a concentration of 0.04 ppm. Manganese was more easily detected than either zinc or copper but less easily detected than iron. A manganese concentration of 3.4 ppm was tasted by 5 per cent of the panel.

Further comparison of the taste thresholds of these metals is noted in the range of concentrations from that just detectable by the most acute 5 per cent of the panel to those at which 95 per cent of the panel tasted the metal. This comparison, shown in Table 6,

TABLE 4

Taste Threshold Frequencies at Varying Concentrations of Manganous Ion

Manganese Concentration *ppm*	Distilled Water	Spring Water
	Cumulative Threshold Distribution—%	
1	0.7	0
4	6	0
8	14	0
16	26	0.05
32	47	1
64	67	7
128	82	43

TABLE 5

Taste Threshold Frequencies for Various Concentrations of Metals in Distilled Water

Ion Concentration *ppm*	Zinc Sulfate	Cupric Chloride	Ferrous Sulfate	Manganous Sulfate
	Cumulative Threshold Distribution—%			
0.05	*	*	6	*
0.5	*	*	26	0.15
1	*	<0.1	34	0.7
2	0.5	1.4	44	2
4	4.5	19	53	6
8	19	60	63	13
16	47	95	71	26
32	78	>95	81	45
64	96	>95	88	66

* Not detected.

TABLE 6

Range of Concentrations in Distilled Water Detectable by Panel Members

Metal	Threshold Distribution	
	5%	95%
	Concentration—*ppm*	
Zinc	4.3	62
Copper	2.6	15.8
Iron	0.04	256
Manganese	0.9	487

reveals that iron and, to a much lesser degree, manganese show a remarkable spread of concentrations. Conversely, copper shows a small range. Although the full significance of this observation cannot be assessed at this time, the small range for copper does have the practical significance of pointing out that small increases in copper content result in rapid changes in threshold distribution.

With the exception of the ferrous ion, solution of the metal ion in spring water increased the taste threshold. For example, at the 50 per cent distribution level, the values for zinc sulfate were increased from 17.6 in distilled water to 27.2 ppm in spring water; the increase for copper ion was from 6.6 to 12.7 ppm, and for manganese it was from 45 to 166 ppm. This trend was reversed with ferrous ion, for which the values were 3.4 and 1.8 ppm for distilled water and spring water respectively.

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Style Manual for Journal Authors

Editorial Statement

An editorial statement specifying the mechanical and style requirements for Journal manuscripts and outlining briefly the steps involved in Journal publication procedure, with a supplementary discussion of the rules of oral presentation.

A MANUSCRIPT is the raw material from which each JOURNAL article is fabricated. Only to the extent that the manuscript is of superior quality can the published article be of superior quality. Just as it is expensive to produce a product of standard quality from an inferior raw material, it requires added effort and time to develop even a fair presentation from a poorly prepared manuscript.

At the other end of the production process, quality again hangs in the balance. The superior quality of any raw material is lost if the manufacturing process is slipshod; a good manuscript becomes a poor article if the editing or the proofreading is carelessly handled.

Because the inferior manuscripts received are almost always inferior from a mechanical standpoint rather than by reason of their subject matter or its interpretation, and because poor articles are usually the result of an author's misconception of his part in the publication process, the Association presents herewith a guide to the mechanics of manuscript preparation and to the proper handling of proofs. Though by no means a complete manual of style, so far as they go these specifications are to be considered the standard for JOURNAL authors. Additional information regarding the points covered and detailed advice concerning the organization and development of the technical article may be obtained from a number of books dealing specifically with those subjects.[1, 2]

Manuscript Preparation

Too much emphasis cannot be placed upon the basic mechanical requirements of manuscript preparation. If no other rules than the fundamentals of proper manuscript typing are followed, the editor will have been relieved of an onerous eye-straining task of squeezing and patching that cannot but distract him in performing the more important functions of editing, and the typesetter will have been relieved of the costly necessity of guessing his way through a labyrinth of confusing interpolations.

These rules are fundamental:

1. Every manuscript should be *typewritten* on one side of $8\frac{1}{2} \times 11$-in. white paper, capable of taking ink and substantial enough not to curl.

2. Every part of the manuscript should be *double spaced*. Tabular material, lists of references, and quota-

tions require much more marking than straight copy, so it is particularly important to allow the editor and the printer ample room between lines to write in their instructions to the typesetter.

3. Margins throughout the manuscript should be *at least 1 in.* on both sides and top and bottom.

4. The *original manuscript*—never a carbon copy—should be submitted for publication; extra copies are helpful, but the original should always be sent.

In addition to these basic requirements, there are other rules of preparation which will eliminate confusion both in editing and in reading the paper before an audience:

Long words at the ends of lines should not be split to the next line, as the hyphenation necessary makes typesetting less accurate and reading more difficult.

Tabular material, reference data, and footnotes should be typed on separate sheets. As they are not typeset on the same machines as the text of the paper, they must at some point be separated from the main portion of the manuscript. As they are not usually read as part of the oral presentation, they merely interrupt the speaker.

Indention should not be relied upon to subordinate or set off portions of the text, as that method does not lend itself to use in the narrow JOURNAL columns. Speakers, too, will find the use of numbered paragraphs or subtitles much less difficult to handle than any means of oral indention yet devised.

Capitalization should never be used as a means of emphasis. In the printed article, capital letters are both cumbersome and ugly. In both printed and typewritten form, they are difficult to read.

Underlining for emphasis should be held to an absolute minimum. Not only do the resulting italic letters detract from the appearance of the JOURNAL article, but the method defeats its purpose if overused.

Titles

The title of a paper should be a key to its contents, not an abbreviated boldface version of the discussion itself. It should be long enough to be specific, but short enough, preferably, to fit on a single line—short enough, too, to be remembered. A good title maintains the tone of the paper itself and classifies its story briefly and pointedly. An examination of some recent issues of the JOURNAL will indicate the general type preferred and the space limitations involved.

On a separate sheet of paper, together with the title, there should be included copy for the byline and the introductory note which appears directly below it.

For the *byline*, the author should generally use his first name, middle initial and last name, unless he does not regularly employ that form of address.

For the *introductory note*, he should give complete information in the following form:

A paper presented on (date), at the (section name) Meeting, (city of meeting), by (author's name), (author's title or position), (author's business affiliation), (author's complete mailing address).

Although only the city and state of the author's address are given in the printed note, the full address is required in manuscript, so that correspondence and proofs may be properly

directed in preparing the paper for publication.

Subheads

Subheads help the reader and enhance the printed presentation of a paper. If the author has done a good job of organization, he will have little trouble in developing and placing headings in positions which correspond with the divisions and subdivisions of his outline. Three types of subheads are used in the JOURNAL:

1. *Major subject headings,* such as the two, "Manuscript Preparation" and "Publication Procedures," used in this document, are rarely necessary in the ordinary JOURNAL article. They are required only when a discussion treats of two or more distinct major subjects. When included, they should be typed centered on the manuscript page with at least two spaces above and below to allow the editor room to mark in type specifications.

2. *Ordinary sideheadings,* such as the boldface "Subheads" above, are used to indicate the various points considered in discussing the subject of the paper. These heads are used in virtually every article printed; and for the large majority of articles they are the only heads required. In placing them in the manuscript, the author should type each on a separate line, flush to the left margin, with at least two spaces above and below.

3. *Minor headings,* such as the italicized *"Approach and Tone" and "Terminology"* under the sidehead "Other Style Requirements," are required only when the material under any one subhead needs further breakdown for clarity or emphasis. Ordinarily, when required at all, such breakdowns need be used only under one or two subheads in an article, particularly where the subdivided section is such a general repository as that mentioned above. Such minor headings should be underlined in typing, and should be placed on separate lines, flush to the left margin, with at least two spaces above and below.

Reference to some recent JOURNAL articles will give the author a good general picture of the proper use of subheads, but some further points of style should be emphasized:

Subheads should be written in *phrase,* rather than clause, form. Although often effective, the clause form is for the most part out of character in JOURNAL articles as well as difficult to handle in the narrow columns used. Thus, the phrase form has been made standard for all articles—not "How to Prepare a Manuscript," but "Manuscript Preparation."

Subheads should be short, preferably not more than two or three words, so as to fit on one line.

Subheads should be typed in *capitals and lower case,* never all capitals.

At least *two spaces* should be left *above and below* each subhead to allow the editor space to write in his instructions to the printer.

Although it is impossible to give any general rule for the number of subheads to be used, authors should remember that too many heads will make the presentation choppy as well as unattractive, and that too few will make it formidable to the reader and difficult to follow.

Illustrations

Good illustrative material can perform an important function in clarifying the written presentation of any subject, but to do so it must be both

pertinent and intelligible. Photographs, charts, graphs, and diagrams which meet these requirements should be employed just as often as they add information to or aid understanding of the text. All such illustrations should be submitted with the original manuscript.

For proper reproduction in publication, clear glossy prints of photographs, postcard size or larger, and original drawings or legible photostats are required. Negatives or slides should not be submitted unless the originals are absolutely unavailable, because they are difficult to process and do not usually produce satisfactory printed results. As line drawings can be restyled by the Association's draftsman, it is not absolutely necessary that JOURNAL style be followed in their preparation. Conformance with that style, however, will effect economies in time and expense and will eliminate the possibilities of error in redrawing. All illustrative material can be returned to the author after publication of the article, if desired.

In selecting photographs to be used as illustrations, the author must take into consideration the fact that only those which present strong contrasts of light and dark will reproduce well and give the clarity of detail required. In preparing them for submittal, he should remember that photographs are fragile and that the reproduction process is a sensitive one. Marking of any kind on the face of a photograph, typing or writing on the back, the use of paper clips or staples, and bending or folding all have a direct, adverse effect upon the ultimate engraving. Thus it is necessary to exercise extreme care in handling. By limiting his markings to a figure number on the border of the photograph and by the use of backing board in the transmittal envelope, the author can help to assure proper reproduction.

In developing the drawings for illustrative purposes, the author will do well to consult first the related specifications of the American Standards Association and other more generalized discussions of the subject.[3-5] In applying those suggestions specifically to JOURNAL illustrations, however, he must consider two points:

1. Full-page width is $4\frac{3}{4}$ in.; single-column width is $2\frac{1}{4}$ in.; and full-page depth is approximately 7 in. As original drawings must be scaled to these dimensions, it is important that they be prepared in proper proportion. In view of the fact that letter and grid weights must be kept approximately uniform throughout, the simplest system for standardizing drawings is to scale them to twice reproduction size. Reference to recent issues of the JOURNAL will illustrate the results obtained by this method. In any event, reproduction drawings should never be larger than three times the size of the published illustration.

2. Only essential lettering should appear on a drawing. Explanatory notes, data, and supplementary information should be included in the pertinent text wherever possible, or, if that is not feasible, in a note below the figure title.

All illustrations, regardless of type, should be numbered consecutively in the order in which they are referred to in the text. It is standard JOURNAL practice to refer to illustrations by the designations "Fig. 1" or "Fig. 2," and to key each illustration to the pertinent portion of the text.

Figure titles for all illustrations should be submitted with the original manuscript. These titles should be

typed (double spaced) on a separate sheet and should be developed according to the same specifications as given above for "Titles." In addition, a brief statement (in sentence form) of the significance of the illustration is desirable. In the published article, this appears as an italic note below the boldface figure title.

Tables

Tables are a device by which statistics, specifications, and similar data can be presented most clearly, most concisely, and most usefully. As such, they are an important tool of the author and should be employed whenever appropriate to the subject matter. When data are presented in this form, however, it should be remembered that the function of the pertinent text will be limited to their interpretation, not their repetition in another form. The use of a table is not justified if it cannot stand by itself, without a detailed item-by-item explanation.

Reference to recent issues of the JOURNAL will indicate the variety of methods in which tabular material can be handled. Common to all types, however, are the following points:

1. The JOURNAL page dimensions, given in the above discussion of "Illustrations," must be taken into consideration in the planning of tabular columns and depths.

2. All tables should be numbered consecutively in the order in which they are referred to in the text.

3. Each table should be typed double spaced on a separate sheet, giving the table number and its title, developed according to the same specifications as given above for "Titles."

4. If six footnotes or fewer are used, they should be referred to by the following sequence of symbols: *, †, ‡, §, ‖, #. If more than six footnotes are used, superscript letters (^{a}) should be substituted for the symbols.

Footnotes

Ordinarily, the text footnote is an unnecessary interruption of the reader's train of thought and presents a makeup problem for the editor. As it is JOURNAL practice to handle literature citations by reference to a bibliography at the end of the article, at least 95 per cent of the need for footnotes is eliminated. Much of the other 5 per cent can be avoided by slight revisions of the text. In the few cases where a footnote is unavoidable, the author should observe the strictest rules of brevity consistent with the subject.

Text footnotes should be typed double spaced on a separate sheet (following the page on which the footnoted item appears) and keyed to the text reference by a superscript symbol or letter.

References

All literature quoted, abstracted, or referred to in an author's discussion of his subject should be cited by source in a separate bibliography keyed to the pertinent portion of the text by a superscript number. The literature thus cited should be listed in the order in which it is referred to in the text—*not* alphabetically by author. References to different articles (even if by the same author) should be given separate numbers—not grouped under one number. Each reference should be complete (do not use "ibid.," "loc. cit.," or the like). Every reference should be keyed to the text (avoid citing bibliography not specifically related to a point covered in the text).

The bibliography should be typed double spaced on a separate sheet,

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Fig. 1. Sample Manuscript Page of Reference List

If the author has any doubts whatever concerning the form in which a particular reference should be given, all facts that will help the reader to locate the literature cited should be included.

labeled "References," as shown on the sample manuscript sheet, Fig. 1. For the various types of references, the following data should be included:

1. For *books* (Fig. 1, Ref. 1–4), give author's name complete; title of book (underlined); publisher's name and address; edition if other than first and year of publication (in parentheses); and specific page number, if any.

2. For *periodicals* (Fig. 1, Ref. 5–8), give author's name complete; title of article; name of publication (underlined); volume number; issue number, if each issue is paged separately (Fig. 1, Ref. 8); page number on which article begins; and year of publication (in parentheses).

3. For *reports* (Fig. 1, Ref. 9–11), give author's name complete, if included; section title, if any; title of give author's name complete, if inreport (underlined); name and location of issuing agency; year of publication (in parentheses); and specific page number, if any.

These are the basic data required, but the author should remember that he cannot give too complete information concerning the sources of his material. Whatever facts will help the reader locate the literature cited should be included if there is any question concerning the form required for any specific document.

Abbreviations and Symbols

Abbreviations and symbols are shortcuts in writing which can save both the author and the reader time if used judiciously. For this reason, and because they effect great savings in printing space, they should be used whenever confusion will not result. JOURNAL authors must remember, however, that not all interested readers will have an intimate knowledge of all fields on which the water supply industry touches. What may be a common symbol to the hydraulic engineer may mean little or nothing to the treatment plant operator, although the latter may well be interested in an article on water hammer. A most important rule is: *When in doubt, spell it out!*

To extend the use of abbreviations and symbols in technical writing, many organizations have established standards for their specific fields of interest.[6] From such sources, the editorial staff has developed its own list of standard abbreviations for use in JOURNAL articles (see Appendix B). Although not intended to include all permissible abbreviations, the list does cover the most common words and terms in general water supply usage. So far as it goes, it is to be considered the standard for JOURNAL authors. When additional abbreviations or symbols are used, the author should include the spelled-out words or terms in conjunction with their first occurrence in the manuscript.

Other Style Requirements

The foregoing discussion of style requirements has been concerned with the major components of the JOURNAL article, primarily from the standpoint of mechanical specifications. There are other matters of style which are at least of equal importance to the final product. Such considerations as sentence structure, punctuation, word choice, and the general rules of composition cannot, of course, be discussed in this manual. Any good handbook of English will give detailed guidance in these matters. But a few key points of JOURNAL style which involve basic publication policy merit emphasis here.

Approach and Tone

JOURNAL articles are intended primarily to be technical expositions, pre-

senting information, data, and ideas of interest and value to the water supply field. To achieve the clarity, conciseness, completeness, and accuracy that characterize any good technical article, the author must bear in mind the fact that the average reader will be a general water utility man, not a high school student or a specialist in the particular subject under discussion. He will be interested in obtaining accurate information quickly, without wading through nonessential details. He will be seeking professional information, not a supply of anecdotes or after-dinner stories. He will be interested in *what* was done, not in *who* did it.

In keeping with these requirements, it is of prime importance that the author employ an impersonal (third person) style throughout, crediting any contributions of associates or assistants in a formal acknowledgment at the end of the article. Likewise, it is important that he keep faith with the reader by sticking to the subject at hand to the exclusion of extraneous topics or convictions.

Terminology

Closely allied to the matter of tone in writing is that of terminology. The use of accurate, up-to-date terms is a basic requisite for clarity. Current thinking rarely finds expression in archaic terms. It is important, then, that the author familiarize himself with the latest concepts and terminology which relate to his subject before he presumes to inform his colleagues in the field concerning his own experiences or ideas.

It is out of the question here to attempt any more detailed statement of JOURNAL terminology preferences than to indicate that the lead of Association committees is followed in the various fields in which they are active and that the generally accepted authoritative manuals and handbooks, such as *Standard Methods*[7] and *Bergey's Manual*,[8] are used where they apply. What should be emphasized, however, is JOURNAL practice in the use of trade or product names.

Every author should remember, in reporting experience and experiment, that the description of equipment or materials in basic technical terms will give the reader much more precise and definitive information than reference to some more or less well known commercial designation. Whereas the reader will either be schooled in the general technical language of the field or have easy access to authoritative means to interpret it, he may well be unaware of the peculiar properties of any particular commercial product. The fact that the JOURNAL audience is not only varied, but international, and the fact that readership is not only current, but continuing, make it extremely important that accurate and generally accepted terminology be used throughout. Credits or reference to specific commercial products can then be made in footnote explanations, if such mention seems valuable or desirable.

Spelling and Numerals

The basic rule for good spelling is to consult *Webster's New International Dictionary*, which is the accepted standard for JOURNAL usage. Where latitude is permitted, however, JOURNAL practice has been to prefer the simpler forms. Thus, *gage*, *sulfate*, and *calking* have been preferred to *gauge*, *sulphate*, and *caulking*; *geologic* and *hydrologic* to *geological* and *hydrological*; *formulas* and *indexes*, to *formulae* and *indices*. Such preferences

may best be determined by reference to recent issues of the JOURNAL.

Closely allied to the matter of proper spelling is the proper employment of numerals. Some basic rules are:

1. Round numbers from one to twenty, when used in ordinary text, should be spelled out; but when used in conjunction with other numbers or to designate specific quantities or units of measure, they should be expressed in numerals.

2. Numerals of four or more digits should be divided by commas—for example, "1,234" and "1,234,567."

3. Decimal values below 1.0 should include the zero before the decimal point—for example, "0.12."

4. Approximations should generally be expressed in words rather than in numerals—for example, "about a thousand."

Consistency

The crux of all specifications for style is consistency—consistency in outline, in phraseology, in terminology, in presentation of data—internal consistency from the smallest unit to the article as a whole. Nothing is more vital to the achievement of clarity of expression than consistency of expression. Nothing is more effective in focusing the reader's attention on what is *meant* rather than on what is *said*. Consistency and unity foster concentration and, through it, understanding.

Helpful in attaining consistency is the practice of soliciting outside criticism of the first drafts of a paper. But every author will do well to give his manuscript a final critical review before submitting it for publication, with a view toward eliminating the minor inconsistencies that invariably creep into any original piece of writing.

Publication Procedures

The publication process is one that requires cooperation at every stage. The efforts of the author, the editor, and the printer, and frequently the draftsman and engraver as well, must be coordinated to produce, in the time allotted by the publication schedule, an article that is readable, understandable, and attractive in appearance. Although the editor assumes the responsibility for achieving the overall coordination and timing, he cannot be successful unless the author fully understands his part in the process, and, understanding it, properly fulfills his obligations.

To acquaint JOURNAL authors with the procedures involved in the publication of an article—from manuscript to JOURNAL page—there is presented below a brief discussion of the process, step by step, in which the various rights and duties of the author are outlined. Not all the factors can be considered, but these are the basic considerations.

Manuscript Submittal

The JOURNAL includes two types of articles: papers presented at Association section meetings and general conferences and contributions by authorities in the field. Both have an equal claim to JOURNAL space, based primarily on the particular merits of the manuscript submitted. Each has its own submittal requirements.

Papers presented at AWWA meetings are primarily the property of the Association, so far as publication rights are concerned. The original manuscript, together with all illustrative

material, should be turned over to the officiating section or Association officer at the end of the particular session at which it was presented. If immediate release to that officer is for any reason impractical, arrangements should be made at that time for its early transmittal to AWWA headquarters.

Contributed articles should be forwarded directly to the JOURNAL editor, preferably in duplicate. With the original manuscript should be included a letter of transmittal and any authorization required by the author's employer or by any organization having prior publication rights.

All articles properly submitted are subjected to review as promptly as possible and either scheduled for publication, returned for revision, or rejected. Rejected *contributions* are returned immediately to the authors. Unless otherwise requested, however, rejected *section or conference papers* are held in the Association files for reference.

Editing

Approximately 3 months before an article is scheduled to appear in the JOURNAL, the original manuscript, together with all the pertinent correspondence, is handed to the editor who must prepare it for publication. The editor's job is threefold: he must review the manuscript for sense; he must review it for consistency of detail; and, finally, he must review it for typographic planning. Although these functions overlap considerably, they may best be considered separately.

In reviewing for sense, the editor assumes the viewpoint of the informed JOURNAL reader and endeavors to make such changes as will improve the organization, the clarity, the conciseness, the completeness, and the accuracy of the discussion. It is at this stage, too, that repetitious and extraneous material is deleted. If illustrations are submitted with the manuscript, the editor determines what drawings or photographs will make a definite contribution to the clarity or interest of the article, the number chosen being subject, in part, to limitations of space.

In reviewing for consistency, the editor must ascertain that terminology, abbreviations, symbols, reference data, numerals, and similar details are consistent within the article and are consistent with JOURNAL standards where they apply. He makes such changes in detail as are dictated by JOURNAL style preferences and by accepted standards of good technical writing. If drawings are to be used, the editor recasts the author's originals to the extent required by JOURNAL specifications and submits them to the draftsman for redrawing and lettering.

In reviewing for typographic planning, he marks in all typesetting instructions required by the printer, determines the style of subheads, recasts tabular material as required, and estimates the number of JOURNAL pages the article will fill.

If a paper is well written and if the manuscript has been properly prepared, the editor's job is an easy one, and the author will find relatively few markings on the manuscript beyond the necessary typographic instructions. The well prepared manuscript also gives the editor additional opportunity and incentive to consider the finer points of styling in his general review.

Proofreading

In 1–3 weeks after he has been advised of the scheduled publication of

his paper, the author receives galley proofs of the article, together with his original manuscript. It is at this point that his cooperation is of maximum importance. The close production schedule on which each issue of the JOURNAL must be assembled makes it imperative that proofs be checked and returned within 48 hr of receipt. The fundamental importance of accuracy makes it imperative that proofs be checked carefully and thoroughly. To satisfy both these requirements, it is necessary that the author plan to devote a considerable amount of time to the task out of his immediate schedule. If time does not permit a prompt check, the author should immediately notify the editor of that fact to permit revision of publication plans, rather than hazard a slipshod job. Accuracy is almost always more important than early publication.

Although the editor, too, will read the proofs through from beginning to end, this fact should not lessen the author's diligence, especially in the detailed checking of facts and figures, which must remain the author's responsibility.

A proper proofreading for accuracy of detail must include the following:

1. A check of all *factual material*—tables, design data, production figures, dates, names, and references—against the original manuscript.

2. A check of, and reply to, all *editor's queries* (written in red in the manuscript margin).

3. A check of all *cross references*—to bibliography, tables, and illustrations—to ascertain correspondence. (It should be pointed out here that illustration references will usually have to be checked by title only, as the production schedule rarely permits forwarding of illustration proofs at the same time as galley proofs. Photostats of redrafted illustrations are mailed to the author, along with captions, as soon as they are ready, but the author should *not* delay in returning galley proofs until illustration proofs are received.)

In making the above checks, the author must bear in mind that, although both are perfectionists, neither the editor nor the typesetter professes to be perfect. The best typesetter can press the wrong key, particularly if he is dealing with a poorly prepared manuscript. The best editor can make the wrong interpretation, particularly if the subject matter is unfamiliar to him. It is the author who must protect the original accuracy of his paper.

In checking editorial changes, the author must consider, too, the editor's purpose in making the change. Where style enters in, JOURNAL preference may dictate a change despite the fact that the original statement is in itself correct. Where material has been deleted, it may be because it is repetitious of some other JOURNAL article. Where meaning is confused by a change, it may well be because the original statement was not clear. Nothing is accomplished by an author's arbitrary insistence that his original form be restored; editorial changes are sometimes incorrect, but they are never pointless. Cooperation and compromise are the keys to an improved presentation.

Reprints

Although every author receives a minimum of ten free offprints of his published article, as well as two free copies of the JOURNAL in which it appears, many authors are interested in obtaining additional copies of their arti-

cles for various personal or business purposes. Because production of reprints is most economical when handled in conjunction with the printing of the JOURNAL, it is important that orders be placed *before* the JOURNAL goes to press. To give authors an opportunity to take advantage of these low-cost reprints, an order form is enclosed with each set of galley proofs.

It should be pointed out that all material printed in the JOURNAL is copyrighted by the Association and may not be reproduced without its permission. Such permission is usually granted for reproduction in recognized periodicals, but the Association does not permit reprinting of articles as "separates" except under its own auspices. The Association's policy on quotations and reprinting is set forth in detail in a leaflet available on request.

Makeup and Printing

Once the author has returned his corrected galley proofs (and, if there are drawings, illustration proofs), his part in the publication process is completed and he can expect to see his article in an early issue. *Occasionally*, however, problems of makeup require changes on which he must be consulted, and by the quickest available means of communication. *Often*, last-minute production problems necessitate rearrangement of schedules and consequent postponement of some articles. *Always*, the task of making up, printing, folding, collating, sewing, covering and mailing the JOURNAL takes much more time than the average author expects.

If every author is aware of these factors and is aware, too, of the active role he must play in the publication process as a whole, both the procedures and results of publication will benefit. Insofar as the author understands the editor's problems in transforming the typewritten manuscript into the printed article, they become mutual problems, open to cooperative solution.

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APPENDIX A

The Oral Presentation

All of the considerations involved in the development of a good JOURNAL article hold true also for the preparation of a good speech, but in a number of instances the emphasis changes. This is particularly true where the factors of timing and illustration are concerned. Clearness and conciseness in speaking outweigh all the other requirements of proper presentation. And added to the basic rules of good writing must be three fundamentals of effective speaking:

Stand up! An audience pays more attention to a visible source of speech.

Speak up! An audience is assembled to obtain information on an announced subject. It will be attentive as long as fresh information is forthcoming in clear, hearable language.

Shut up! A speech is over when its point has been made. Garrulousness and garnish merely serve to bury or confuse the issue.

The rules of good speaking should be self-evident to anyone who has been a member of an audience, but certain rules of timing and illustration merit discussion in this context.

Timing

Listener interest, however avid, has a limited endurance; it cannot compete in stamina with reader interest. Thus, it is important in speaking to get to the point early, to discuss the point clearly and concisely, and then to stop. If the subject is technical, requiring length for completeness or extensive detail for thoroughness, it is best to discuss only overall methods, results, interpretations, and conclusions in the oral presentation and to submit a separate full report for publication.

Listener interest is also limited by the ability of the audience to keep pace with the speaker. Thus, rate of speech, as well as length of speech, has an important bearing not only on attentiveness but on the capacity for assimilation.

Studies of audience reaction have indicated that a reading or speaking rate of approximately 120 words per minute is most effective in retaining listener interest. Similarly, it has been found that the average audience saturation point is reached in 20 min. On this basis, then, it can be assumed that, to be most effective, a speech should be limited to ten or fewer double-spaced manuscript pages of text and should be read at the rate of about 2 min per page.

The final consideration in timing is courtesy—to those who arranged the program, to the audience, and to the other speakers. It is patently inconsiderate and uncooperative to ignore the program schedule. Not only does it reflect on the judgment of those who determined the amount of time which the subject merited, but it deprives other speakers of their allotted time. Similarly it is discourteous to place less value on the time or acuteness of the audience than did the program committee in scheduling the presentation. And it must always be remembered that an audience once driven to exhaustion or boredom will be difficult for other speakers to rouse, regardless of the intensity of its basic interest in the subject discussed.

Illustration

As lantern slides are the only really practicable method of illustrating an oral presentation of most water supply subjects, it is important that speakers familiarize themselves with their various characteristics and limitations before contemplating their use. And, in doing so, perhaps the wisest approach will be a negative one.

Good lantern slides are difficult to prepare and difficult to use effectively. Unless they make their point immediately apparent, they merely distract and detract from the presentation. The confusion which usually attends their projection interrupts the speaker's delivery. The darkness required for their showing is conducive to sleep on the part of the audience and to eye strain or stumbling on the part of the speaker. And the entire process, unless rehearsed to perfection, involves a deplorable waste of valuable time.

If, despite these drawbacks, the speaker feels that his subject requires graphical presentation, he should by all means limit the number of illustrations used, ascertain both their pertinence and their clarity, and then have the slides prepared professionally. And in developing the illustrative material, he should also consider these factors:

1. Only such illustrations should be used as add to the presentation by denoting graphically concepts or data difficult of verbal description. Photographs or simple drawings showing space relationships make the best illustrations. Graphs presenting complicated technical data and requiring elaborate explanations merely serve to confuse the listener. Tabular material makes the audience read when it should be listening.

2. Original charts and photographs must be planned and developed to the dimensions of a standard-size slide, and all should be made to fit a single slide size. The two standard sizes used are $3\frac{1}{4} \times 4$ in., with a picture area of about $2\frac{1}{4} \times 3$ in., and 2×2 in., which takes 35-mm film. Both types of projectors are usually available, but the speaker should check carefully with the program committee before going ahead with his plans. Then he should plan his illustrations to fit one type of equipment to avoid the added confusion attending the use of two machines. Original material is usually prepared to three times the size of the slide, but considerations too numerous to discuss here affect this relationship. Before going ahead, the speaker should consult either a good set of specifications on the subject, such as those listed in Ref. 9–11 of the foregoing manual, or discuss the requirements with the photographic shop that will make the slides.

3. When the slides have been delivered, they should be checked carefully against the original material, numbered and labeled clearly, and keyed to the speech.

4. Before the presentation is scheduled, the author should arrange to discuss the projection schedule with the operator assigned. Only if the operator has been given detailed instructions can he be expected to cooperate in making the presentation successful.

The Speech and the Article

As has been suggested, the inherent differences between the listening and the reading audiences make it desirable for the author to use a slightly different approach in presenting his subject to each. Most often this can be accomplished by a judicious pruning or rearrangement of the finished publication manuscript for the oral presenta-

tion. It is often difficult to do this extemporaneously, but it will require no great effort to prepare a reading copy by the use of a pair of scissors and some paste. In adapting the occasional detailed technical manuscript which does not lend itself to such treatment, the author will do well to prepare a separate, simplified discussion for presentation before an audience.

If illustrations are used in the oral presentation, the author must remember that the requirements for lantern slides and those for JOURNAL engravings also vary. Whereas the listener can only look at it, the reader can study an illustration, so that much more use can be made of the graphical technique in the article than in the speech.

Finally, it should be pointed out that the publication manuscript can both gain and lose by its close association with the speech. If the manuscript can be infused with certain of the elements of simplicity and brevity that should be present in the oral presentation, the published article will undoubtedly gain in clarity and readability. On the other hand, if the manuscript is cluttered with the informalities and allusions of the personal approach required in the speech, the article cannot but lose in both clarity and tone. The distinction between author and speaker is a fine one, but an important one to make if both article and speech are to be of equal quality.

APPENDIX B

Journal Abbreviations

acre-foot	acre-ft
alternating-current (adj.)	a-c
ampere(s)	amp
ampere-hour(s)	amp-hr
atomic weight	at.wt
avoirdupois	avdp
barrel(s)	bbl
billion electron volt(s)	Bev
billion gallons	bil gal
billion gallons per day	bgd
biochemical oxygen demand	BOD
board feet (feet board measure)	fbm
brake horsepower	bhp
British thermal unit(s)	Btu
bushel(s)	bu
centigram(s)	cg
centiliter(s)	cl
centimeter(s)	cm
chemically pure	cp
counts per minute	cpm
cubic	cu
cubic centimeter(s)	*use* ml
cubic feet per minute	cfm
cubic feet per second	cfs
cubic foot (feet)	cu ft
cubic inch(es)	cu in.
cubic meter(s)	cu m
cubic micron(s)	cu μ
cubic millimeter(s)	cu mm
cubic yard(s)	cu yd
curie(s)	c
deciliter(s)	dl
decimeter(s)	dm
degree(s)	deg
degree(s) Centigrade	°C
degree(s) Fahrenheit	°F
direct-current (adj.)	d-c
dissolved oxygen	DO
dram(s)	dr
electromotive force	emf
elevation	el
Equation	Eq
ethylenediaminetetraacetate	EDTA
feet	ft
feet board measure (board feet)	fbm
feet per hour	fph
feet per minute	fpm
feet per second	fps
Figure(s)	Fig.
foot	ft
foot-pound(s)	ft-lb
free on board	fob
gallon(s)	gal
gallon(s) (Imperial)	gal (Imp.)
gallon(s) per capita per day	gpcd
gallon(s) per day	gpd

gallon(s) per hour	gph
gallon(s) per minute	gpm
gallon(s) per second	gps
grain(s) per gallon ..... (*convert to ppm*)	
gram(s)	g
horsepower	hp
horsepower-hour(s)	hp-hr
hour(s)	hr
hundredweight	cwt
inch(es)	in.
inch-pound(s)	in-lb
inch(es) per minute	ipm
inch(es) per second	ips
indicated horsepower	ihp
inside diameter	ID
kilocurie(s)	kc
kilocycle(s)	kc
kilogram(s)	kg
kiloliter(s)	kl
kilometer(s)	km
kilovolt(s)	kv
kilovolt-ampere(s)	kva
kilowatt(s)	kw
kilowatt-hour(s)	kwhr
linear foot	lin ft
liters	l
logarithm (common)	log
logarithm (natural)	$\log_e$
man-hour(s)	man-hr
maximum permissible concentration ..	MPC
meter(s)	m
mho(s)	mho
microampere(s)	μa
microinch(es)	μin.
micromicron(s)	$\mu\mu$
micromho(s)	μmho
micron(s)	μ
microvolt(s)	μv
microwatt(s)	μw
mile(s)	mi
mile(s) per hour	mph
milliampere(s)	ma
millicurie(s)	mc
milliequivalent(s)	me
milligram(s)	mg
milliliter(s)	ml
millimeter(s)	mm
millimicron(s)	mμ
million electron volt	Mev
million gallons	mil gal
million gallons per day	mgd
millivolt(s)	mv
minute(s)	min
molar (concentration)	M
molecular weight	mol wt
most probable number	MPN
nanocurie(s) (10^{-9} curie)	nc
normal (concentration)	N
Number(s)	No.
ounce(s)	oz
ounce-foot (feet)	oz-ft
ounce-inch(es)	oz-in.
outside diameter	OD
part(s) per billion	ppb
part(s) per million	ppm
picocurie(s) (10^{-12} curie)	pc
pound(s)	lb
pound(s) per square foot	psf
pound(s) per square inch	psi
pound(s) per square inch absolute	psia
pound(s) per square inch gage	psig
quart(s)	qt
revolution(s) per minute	rpm
revolution(s) per second	rps
roentgen equivalent(s) man	rem
second(s)	sec
second feet (cubic feet per second)	cfs
specific gravity	sp gr
specific heat	sp ht
square	sq
square centimeter(s)	sq cm
square foot (feet)	sq ft
square inch(es)	sq in.
square kilometer(s)	sq km
square meter(s)	sq m
square micron(s)	sq μ
square millimeter(s)	sq mm
United States Pharmacopoeia	USP
volt(s)	v
volt-ampere(s)	va
watt(s)	w
watt-hour(s)	whr
week(s)	wk
yard(s)	yd
year(s)	yr

Notes and Comment

Delhi Hepatitis Epidemic

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As I held the post of superintending engineer, Health Services, Delhi Province, and therefore ex officio engineer to the Delhi Joint Water and Sewage Board, as well as secretary, from March 1943 to October 1947, I was very interested in the paper by Joseph M. Dennis entitled "1955–56 Infectious Hepatitis Epidemic in Delhi, India," published in the October 1959 issue (p. 1288). There are, however, several important discrepancies in the paper which require consideration in order to give a correct picture of the whole occurrence.

The Wazirabad intake was established about 1911 by the Public Works Department of the Government of India and little is known of its operation prior to the formation of the Delhi Joint Water and Sewage Board in 1926, except that the intake rate was 5,000 gpm. The sills of the original intake on the right bank were fixed at river level 660.0, only 6 in. above the river bed, and considerable trouble was experienced with intake of sand when the river was only 18–24 in. deep during the dry season. The sills were therefore raised first by 9 in. and subsequently by a further 9 in., but because the river level falls to 662.5, or lower in a very dry year, the head of water over the raised sills set a very definite limit to the rate of intake. That limit was reached in 1932. The construction of temporary bunds [dikes] of sandbags to hold up the water level at the intake was therefore resorted to and continued each dry season until the new intake was brought into operation in 1946 when the rate of intake had become 25,000 gpm.

The bunds were a continual source of worry and expense, as they were easily damaged by increased flow down the river, resulting from temporary canal closures, which took place with little or no warning. Such damage had to be repaired quickly to avoid reduction in the pumping rate. Materials had to be kept in readiness and a large labor force made available at short notice. Moreover, the openings in the bunds had to be contracted from time to time to compensate for the reduction in flow as the dry season progressed.

With the accelerated demand for water, which resulted from war conditions, it was evident that the existing intake would soon be too small to meet the demand. As the cost of the bunds, with maintenance from December to July, amounted to Rs 50,000 ($10,500) per annum, a new intake was designed to take in sand-free water at 25,000 gpm with a river level at 661.5. The existing intake was left for subsequent remodeling to handle 15,000 gpm at that level.

In 1943, the southern end of the sand bank was still upstream of the intake but was gradually extending southward, and as the greater part of the dry-weather flow passed on the far side of it, shoaling in front of the intake commenced at a somewhat alarming rate in 1944. Small training banks were therefore constructed across the

channel at the upstream end of the sand bank before the onset of the rains, in order to induce scour in the channel along the right bank of the river as the water level rose. This gave such very successful results that it was repeated on a smaller scale the following year, with the result that the dry-weather channel was brought to the right bank of the river and held there during 1946 and 1947 without further training. The other was silted up.

It can thus be seen that the real cause of the epidemic at Delhi was the loss of control of the river. The excavation of a channel as shown in the illustration on the cover of the October 1959 JOURNAL, would not only be useless but would be distinctly dangerous, for during the following monsoon, flood currents directed at the river bank would cause heavy damage by scour.

Had proper control of the river been maintained it would not have been possible for sewage from the Najafgarh Nallah, 700 ft downstream, to gain access to the water in 1955. Thus it is hardly fair to blame the filter plant for not doing a job for which it was not designed. In regard to scouring of the filters with compressed air, no precautions beyond slow initial opening of the valves were necessary. Once the air had spread evenly over the bed, the valves were opened fully. Air has been used since 1911 without any evident damage to any filter.

As regards the chlorination equipment, no mention has been made of the auxiliary chlorinating apparatus located at the inlets to the principal service reservoirs when I handed over charge in October 1947, although it is probably still in existence.

In the period of which I write, close liaison was maintained with the Public Health Laboratory, and regular reports were received from them on the bacteriological quality of the water. Normally there was an absence of lactose fermenters in 100 ml, but on the rare occasion when the MPN was 1 or 2, the result was sent to me at once and immediate inquiries were made and the necessary action was taken.

The dysentery figures quoted in Table 2 could be very misleading, as no distinction has been made between bacillary and amebic types of dysentery. The former was very prevalent in Delhi and probably still is, being largely due to other causes.

Unless appreciable alterations have been made since my day, there is no sewage entering the river between the Najafgarh Nallah and the Okhla Barrage, although several storm water drains discharge to the river during the monsoon.

The effluent from the large sewage treatment plant at Okhla is principally used for irrigation purposes, and any discharge to the river takes place below the Okhla Barrage so it is not evident how the Okhla water treatment plant could have treated water containing abnormally high concentrations of infectious hepatitis virus.

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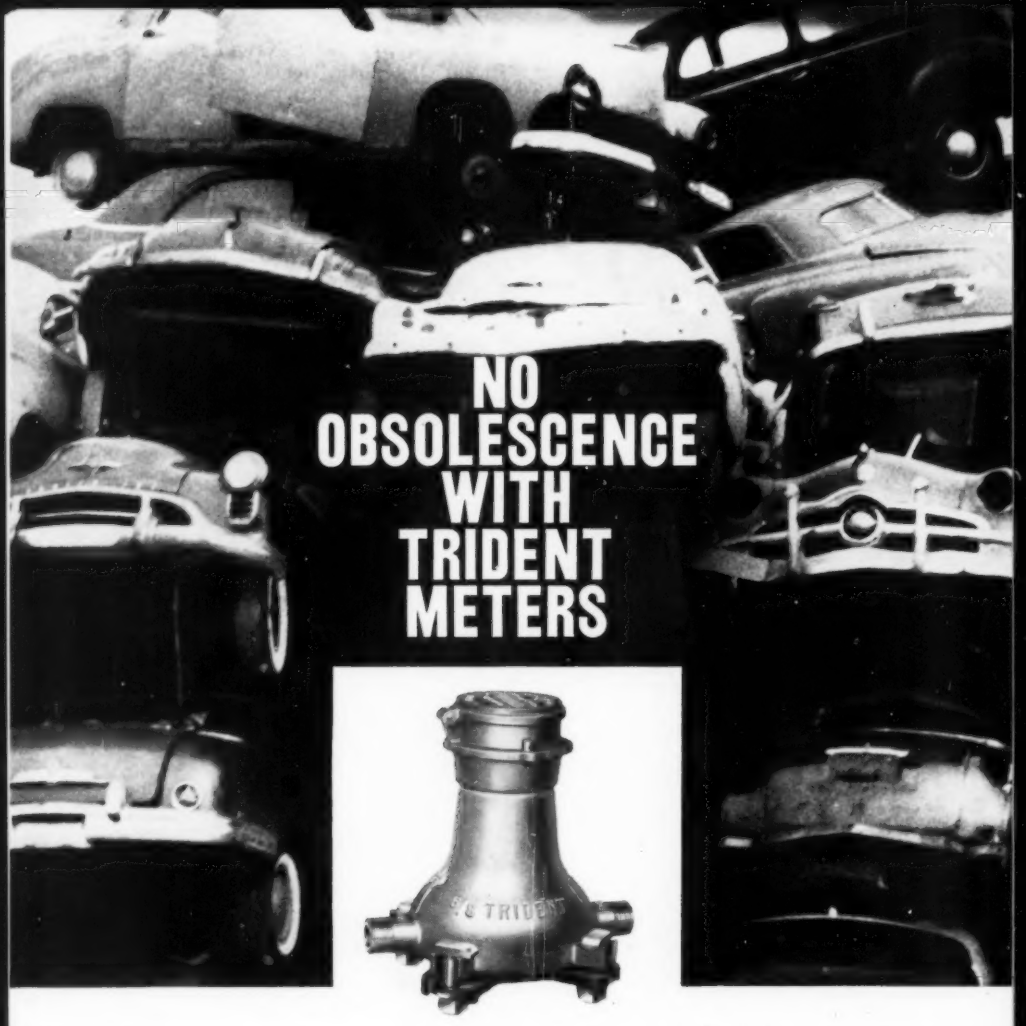

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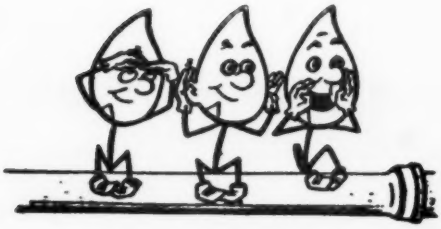

Percolation and Runoff

Bal Harbour, which for us isn't, for you will have been, but we can join you in saying that it certainly was the best of all 80 of AWWA's Conferences to date. Most of the details will have to wait until not the next issue, but the one after, but we won't hold back in reporting that these are the officers and directors who took over on Thursday evening, May 19:

President—C. F. Wertz, director, Dept. of Water & Sewers, Miami, Fla. Born in Reading, Pa., in 1898, he received a B.S. in sanitary engineering from Pennsylvania State College in 1920, after which he began his professional career as assistant engineer with the State Board of Health. From 1926 to 1941 he held assignments with various engineering firms in New York, Pennsylvania, and Ohio. In 1941 the firm of Day & Zimmermann, Inc., of Philadelphia, sent him to Miami on a property management assignment for the city's Dept. of Water & Sewers. He served in that capacity until 1955, when he obtained his present position as department director. He is a registered professional engineer in Pennsylvania and Florida.

A Life Member of AWWA (joined in 1924), he served the Florida Section as vice-chairman (1946), chairman (1947), and national director (1951–54). The section nominated him for the Fuller Award in 1947. He has been a member of the Water Works Practice Committee, the Committee on Joint Administration of Water and Sewer Facilities, and the Committee on Procedure for Disinfecting Water Mains. He was chairman of the Convention Management Committee both in 1951 and 1960. He was AWWA vice-president in 1959–60.

Other technical societies to which he belongs are ASCE, WPCF, Florida Sewage Works Assn., Pennsylvania Sewage & Industrial Wastes Assn., and Pennsylvania Water Works Operators Assn.

Vice-President—John W. Cramer, senior partner, Fulton & Cramer, Lincoln, Neb. Born in North Platte, Neb., in 1914, he received a B.S. in civil engineering from the University of Nebraska in 1940. From 1940 to 1945 he had engineering assignments with several companies in California and Nebraska. He became a partner of Fulton & Cramer in 1945 and senior partner in 1959. He is a registered professional engineer in five states.

A member of AWWA since 1948, he has served the Nebraska Section as

(*Continued on page 46 P&R*)

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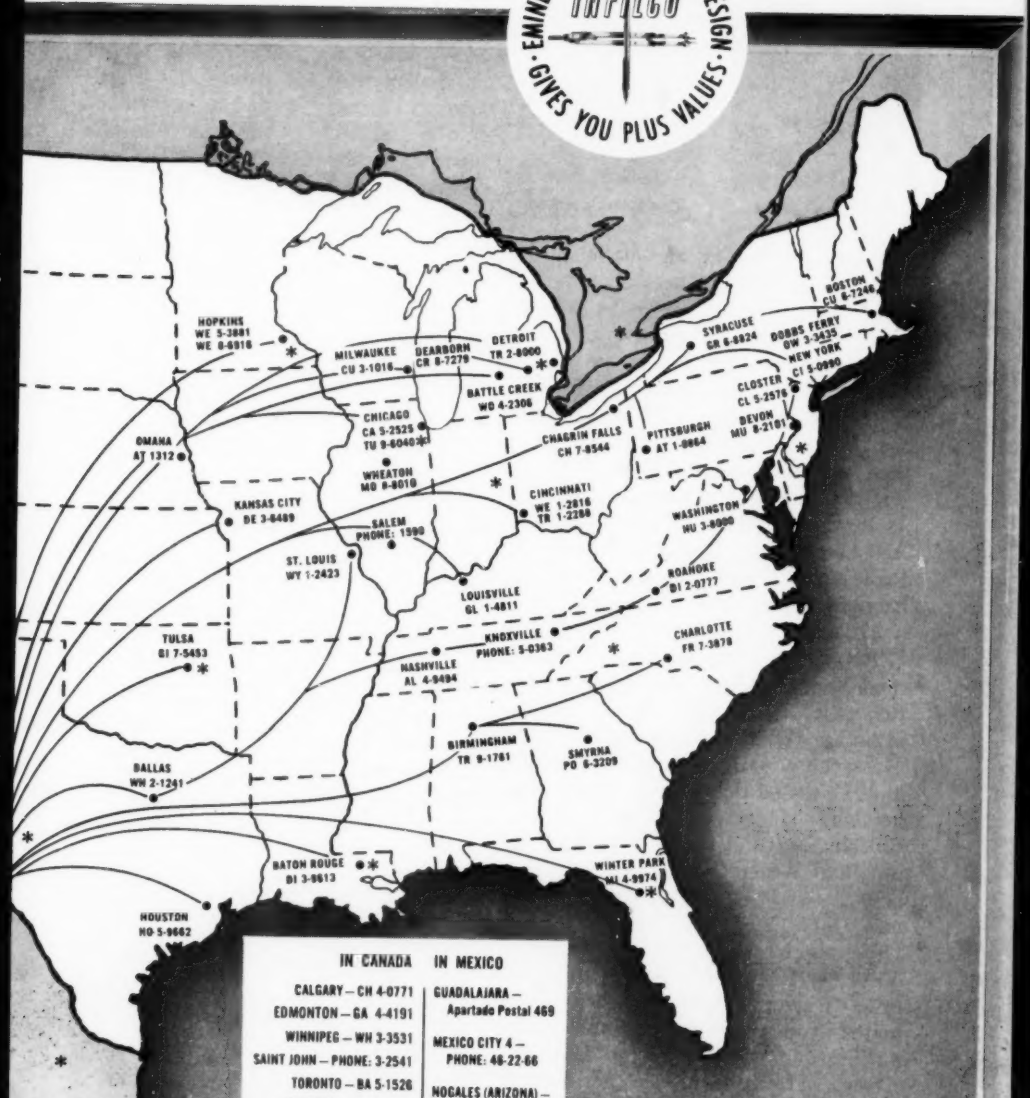

(Continued from page 43 P&R)

V. P.—Cramer

Treas.—Orchard

secretary (1948–51) and national director (1951–53). The section nominated him to receive the Fuller Award in 1954. He has been active in the Water Resources Division, as trustee (1954–56), secretary-treasurer (1956–57), vice-chairman (1957–58), and chairman (1958–59). He has also been a member of the Committee on Highway Relocation Costs.

Other professional affiliations include ASCE, ASME, National Society of Professional Engineers, and Nebraska Engineering Society (past-president).

Treasurer—William J. Orchard, consultant, Wallace & Tiernan Inc., Belleville, N.J. Born in Boston, Mass., in 1888, he was graduated from Massachusetts Institute of Technology in 1911 with a degree in sanitary engineering. He served with the Massachusetts Board of Health and the Metropolitan Water Commission, and also held the post of assistant sanitary engineer with the New Jersey Health Dept. In 1915 he entered the employ of the Wallace & Tiernan organization. During World War I he originated and developed mobile water purification equipment for the US Army. He rose to the position of general manager of Wallace & Tiernan, retiring in 1954 but continuing as consultant to the company.

An Honorary Member of AWWA (joined in 1917), he received the Diven Medal in 1954 and the Jordan Achievement Award in 1956. A director for many years, he has served as chairman of the Convention Management Committee and as a member of the Executive Committee and the General Policy Committee. He was chairman of the Finance Committee from 1951 to 1957, when he was elected treasurer. Other organizations to which he belongs include WSWMA (past president), NEWWA, WPCF, and APHA.

SECTION DIRECTORS

California—H. Cristopher Medbery, engineer of design and water production, San Francisco Water Dept. Born in Lebanon, S.D., in 1909, he received his B.S. in civil engineering from the University of California in 1936. He joined the department's purification division in 1936, became engineer of water purification in 1943, and attained his present position in 1954.

A member of AWWA since 1936, he served the California Section as secretary-treasurer (1948–49), vice-chairman (1953), and chairman (1954). He was chairman of the Association's

California—Medbery

Chesapeake—Werner

(Continued on page 48 P&R)

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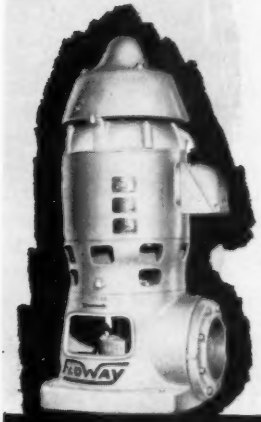

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(Continued from page 46 P&R)

Connecticut—Bell

Cuban—Plana Astienza

Water Purification Division in 1955. He is a member of ASCE and a registered professional engineer in California.

Chesapeake—Bernard L. Werner, director of public works at Baltimore. Born in Baltimore in 1902, he attended Carnegie Institute of Technology and Johns Hopkins University. He joined the city's Bureau of Water Supply in 1925 as assistant civil engineer and served on several important city construction projects. He was appointed assistant chief of the Bureau of Water Supply in 1951, chief in 1955, and to his present position in 1959.

An AWWA member since 1942, he has served the Chesapeake Section as chairman. He has also been president of the Maryland Section of ASCE.

Connecticut—E. Arthur Bell, general manager and chief engineer, Stamford (Conn.) Water Co. Born in 1906, he received his B.S. from Rutgers University in 1928. He then became an assistant engineer with the consulting firm of Clyde Potts in New York City. In 1937 he became engineer and water superintendent for the borough of Essex Falls, N.J. He assumed his present position in 1955.

A member of AWWA since 1937, he was nominated by the New Jersey Section to receive the Fuller Award in 1955.

Cuban—Luis Plana Astienza, engineer in charge of design for the National Aqueduct and Sewerage Commission, Havana. Born in Cienfuegos, Cuba, in 1928, he obtained his degree in civil engineering from Havana University in 1952. Before obtaining his present position, he had several engineering assignments, including those with InterAmerican Geodetic Service, oil refinery construction projects, and Cuba Nitro.

A member of AWWA since 1956, he was chairman of the Cuban Section in 1959.

Florida—John R. Kelly, director of public utilities, Gainesville, Fla. Born in Mayo, Fla., in 1909, he attended the University of Florida and began his affiliation with the city of Gainesville as oiler in the municipal power plant. After promotions to fireman, operator, and assistant superintendent, he became superintendent of the plant in 1946. In 1950 he was appointed as director of public utilities.

A member of the Association since 1947, he was chairman of the Florida Section in 1956–57. He is also past-

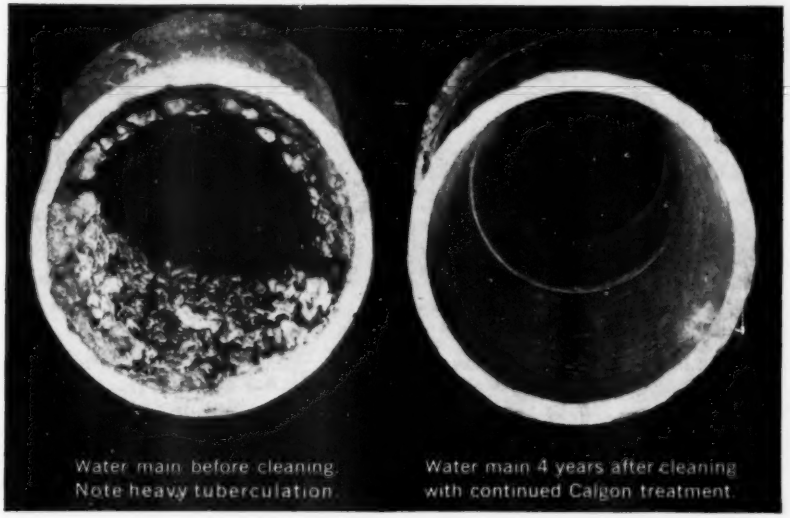
Fla.—Kelly

Ill.—Frye

(Continued on page 50 P&R)

CALGON KEEPS FLOW RATES CONSTANT AFTER MAIN CLEANING

in 4-Year Portland Water District Test



Water main before cleaning. Note heavy tuberculation.

Water main 4 years after cleaning with continued Calgon treatment.

Part of the Portland, Maine, Water District System supplies Sebago Lake water to Gorham Village. An 11,000-foot, 8-inch main was the main feed between a booster station and a standpipe at the far end. This main had not been cleaned for 20 years, and it was found that the flow coefficient "C" had dropped to between 50 and 56 due to massive tuberculation.

Replacement or reinforcement of this main would be expensive, so it was decided to try cleaning a 4,000-foot section of the main, and use this as a test section to determine the effectiveness of chemical treatment to retard corrosion. Calgon® and Calgon® Composition TG were chosen for this test.

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(Continued from page 48 P&R)

Intermountain—Wilson

Montana—Wiel

president of Florida Municipal Utilities Assn.

Illinois—Horace R. Frye, superintendent, Water & Sewer Dept., Evanston, Ill. Born in Chicago in 1904, he attended Crane College, Northwestern University, and the University of Illinois. Employed by the city of Evanston in 1928 as water chemist, he became assistant superintendent in 1938 and superintendent of water in 1942. He assumed his present position in 1954.

A member of AWWA since 1934, he served the Illinois Section as chairman in 1948 and was nominated to receive the Fuller Award in 1957.

Intermountain—Charles W. Wilson, superintendent, Salt Lake City (Utah) Dept. of Water Supply & Water Works. Born in Salt Lake City in 1909, he graduated from the University of Utah in 1931 with a B.S. in business administration. Since then he has been employed with the Salt Lake City Corp. (predecessor of the department) in various capacities. He became superintendent in 1952, since which time he has been the department's corporate representative in AWWA.

He has been secretary-treasurer of the Association's Management Division and was the first chairman of the Intermountain Section (1958).

Montana—Kurt Wiel, city engineer and water superintendent, Miles City, Mont. A graduate of the University of Washington, he joined the engineering department of the Chicago, Milwaukee, St. Paul & Pacific Railroad in 1928, where he remained until 1933, when he was appointed to his present position.

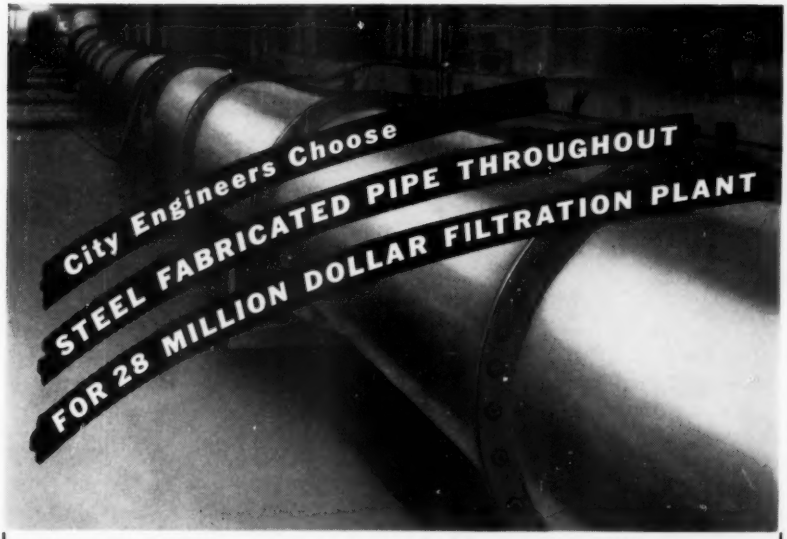
A member of the Association since 1934, he served as chairman of the Montana Section in 1940 and received the Fuller Award in 1956.

North Central—M. D. Lubratovich, director of public utilities, Duluth, Minn. Born in Hammond, Ind., in 1909, he graduated from the University of Wisconsin in 1932, after which he worked for the Minnesota State Highway Dept. (1933–40). He began his service with the city of Duluth in 1940 and assumed several positions until he became director of public service in 1956 and director of public utilities in 1958. Since 1959 he has also served as administrative assistant to the mayor.

North Central—Lubratovich

Ohio—Tatlock

(Continued on page 52 P&R)



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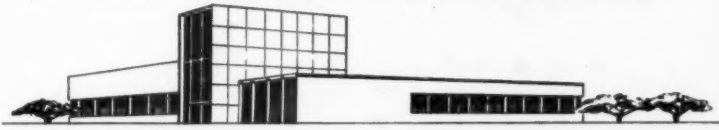

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(*Continued from page 50 P&R*)

A member of AWWA since 1949, he was chairman of the North Central Section in 1957–58. He is a member of WPCF, ASCE, National Society of Professional Engineers, and American Gas Assn.

Ohio—Myron W. Tatlock, partner, Ralph L. Woolpert Co., Dayton, Ohio. Born in Canton, Ind., in 1892, he received his A.B. in physics from Indiana University in 1916. He was assistant engineer at the Indianapolis (Ind.) sanitation plant from 1919 to 1925 and assistant to the plant's superintendent in 1925–28. He was employed by the city of Dayton as engineer and plant superintendent from 1928 to 1942, when he look a leave of absence to serve in the US Army Engineer Corps, retiring as a lieutenant colonel in 1946. In 1946 he assumed his present position as a consulting engineer.

Southwest—Williams

Manufacturer—Alt

A member of AWWA since 1928, he was chairman of the Ohio Section in 1957. He is a member of ASCE, WPCF, and American Public Works Assn. (vice-president).

Southwest—Johnie E. Williams, superintendent, San Angelo (Tex.) Water Dept. Born in Marshall, Tex., in 1908, he received his A.B. from Howard Payne College in 1935. A teacher from 1931 to 1936, he was with the Texas Highway Dept. in 1936–40 and became chemist and operator of the Brownwood, Tex., water plant in 1940. From 1943 to 1947 he served as an operation engineer with the US Army and then instructed at Texas A&M College until 1950, when he assumed his present position.

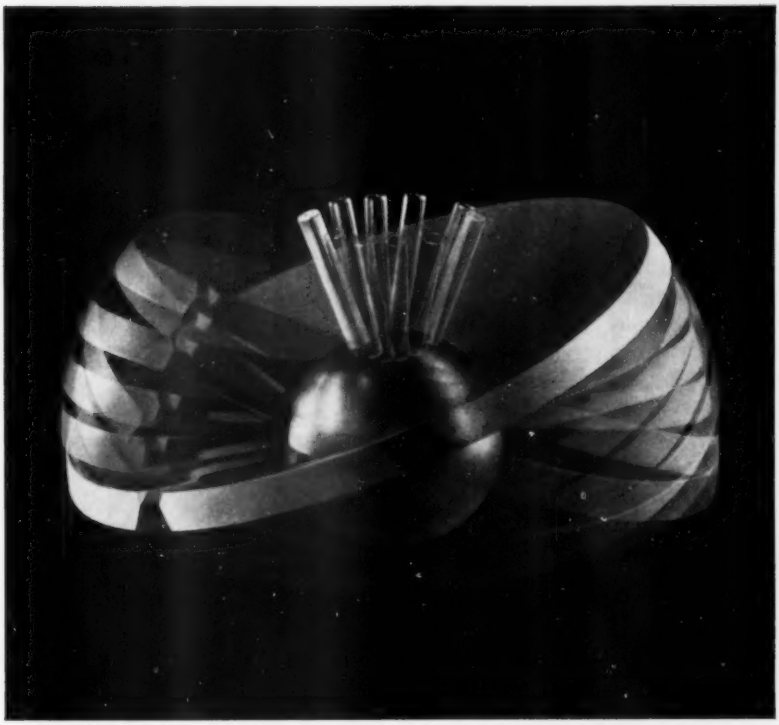
An AWWA member since 1947, he was vice-chairman of the Southwest Section in 1954 and chairman in 1955. He is a past-president of the Texas Water & Sewerage Assn. and a director of the state's Water Conservation Assn.

Manufacturer—Edward E. Alt, sales representative, Chicago Bridge & Iron Co., Chicago, Ill. Born in Chicago in 1892, he received his degree from Massachusetts Institute of Technology in 1915, after which he worked for an architectural firm until 1918. He has been with Chicago Bridge & Iron Co. since that time.

A member of AWWA since 1941, he was chairman of the Illinois Section in 1951–52 and represented the section as national director in 1954–57. He is also a member of Illinois Society of Professional Engineers and the representative of his firm in WSWMA (president in 1959).

Joseph A. Holmes, formerly president of Nalco Chemical Co., has become vice-chairman of the board of directors. A member of AWWA since since 1926, he is a Life Member. Thomas C. Jones succeeded him as president.

(*Continued on page 54 P&R*)



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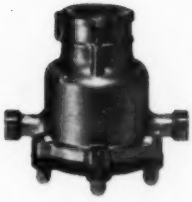

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(Continued from page 52 P&R)

The 'Big Inch' these days is the one that Chicago wants to divert from the Great Lakes to help flush its sewage down to the Mississippi. And there are six states—Minnesota, Wisconsin, Michigan, Ohio, Pennsylvania, and New York—that have been fighting hard not only not to give 'em an inch, but to get back some of inches lost in past years, since Chicago began, at the beginning of the century, to take water from Lake Michigan and not return it. The additional diversion now being requested amounts to approximately enough water to lower the level of the Great Lakes by an inch—an inch which will, the six states say, have a significant effect upon navigation and upon the output of hydroelectric power, not to mention its detrimental effect upon relations with Canada. Having succeeded, at least temporarily, in sidetracking action on the diversion measure—the 89th to appear in Congress since 1933—the Lake States are now looking forward to Supreme Court action on their request to reverse an earlier decision and force Chicago to return to Lake Michigan the water it is now diverting. It is estimated that the direct cost to Chicago of such a requirement would be at least $300,000,000, but that the resulting pollution of the city's beaches and its source of water supply would be an even more expensive problem. Not only what price water, but to whom seems to be the question—and every inch a big one!

(Continued on page 56 P&R)

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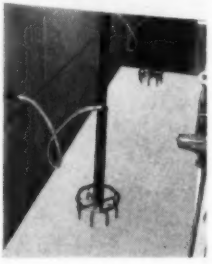

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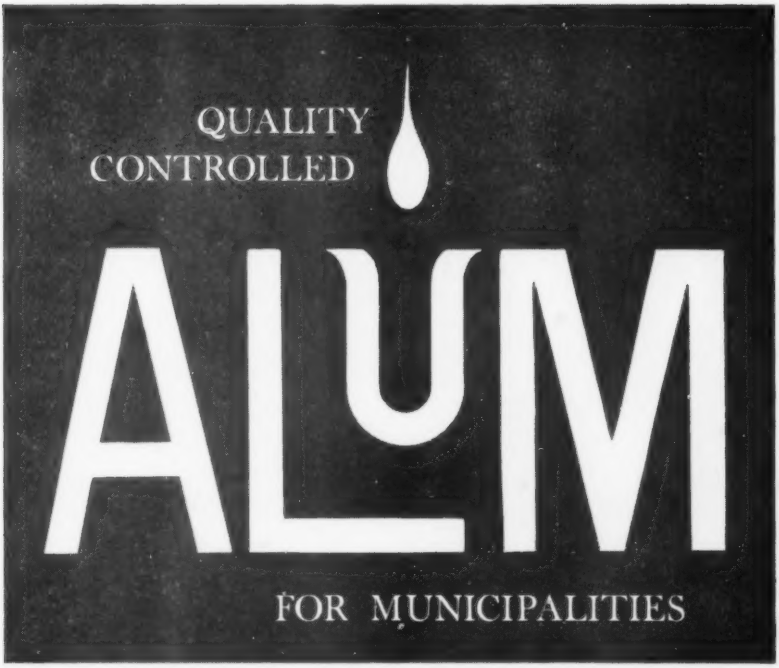

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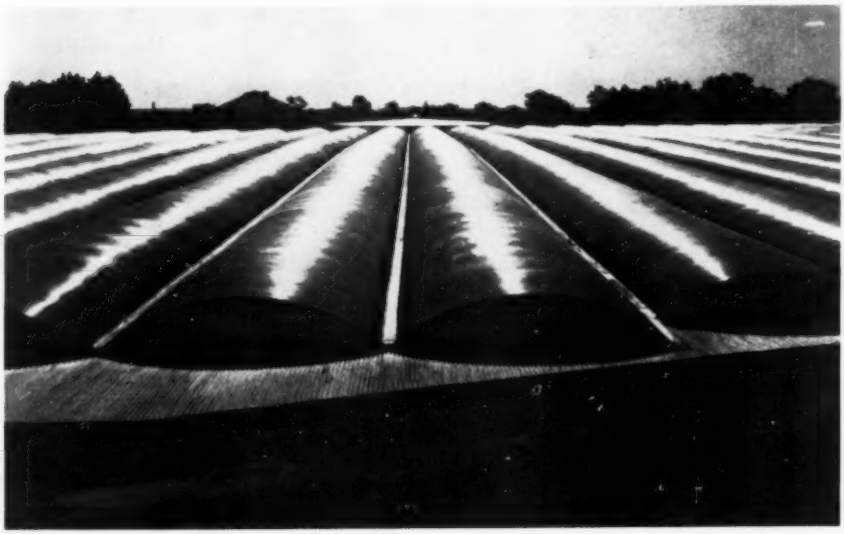
(Continued from page 54 P&R)

Cover is what New York City's water commissioner, Armand D'Angelo, was running for, instead of after, when the news came out that he was considering the possibility of covering the city's 372 acres of distribution reservoirs as a means of protecting the water supply against pollution. A host of critics, including no less a figure than Park Commissioner Robert Moses, immediately attacked the idea, not only for the expense (approximately $50,000,000) which it would involve, but for the fact that covers would destroy the natural beauty of the lakes and rob the water birds (so help us) of a haven. Whatever the merits of arguments concerning the possibilities of using the covers for athletic fields or of cutting the reservoirs out of the distribution system entirely and, thus, preserving the lakes for recreation, we can only marvel at the indulgence of those who would find a place for the seagull in their drinking water.

Under cover, meanwhile, Pawtucket, R.I., put its 20-mil gal Stump Hill Reservoir, using a new type of arched aluminum roofing that does not require inside supports. Fabricated of 16½-ft Kaiser 0.032-in. aluminum sheets arched to span 15 ft, the roof can support 30 psf. And though the surface is hardly suitable for tennis courts (see cut), the cover does serve to keep the water clean and cool. Cost installed, with walkways and incidental work, totaled $1.39 per square foot.



At that rate, New York could cover up for less than half the $50,000,000 and invest the rest in gull shelters—perhaps between the sheets.

Hydrodynamics Div. is the new organizational name for the former Peerless Pump Div. of Food Machinery & Chemical Corp.

(Continued on page 58 P&R)

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(Continued from page 56 P&R)

Anatomical disharmony and vocabularian parasitism are two clues to the difficulty of making accurate threshold odor tests provided by one Roy Bedichek in his book, *The Sense of Smell* (Doubleday, New York). The disharmony stems from the fact that the evolution of man's exterior nose has been diverted from the line generally taken in mammals by his assumption of an upright position, distorting the inside structure of the organ so that it cannot cooperate smoothly with other parts of the human machine. The parasitism comes from the fact that the sense of smell has comparatively few words which belong to it exclusively, thus making it difficult, if not impossible, to report accurately on the tens or, even, hundreds of thousands of odor stimuli that may be detected by the human nose.

Rather discouraged by these revelations from expecting human odor analyses ever to amount to anything more than a rule of thumb, we were excited at the possibility suggested by the statement:

> In the final analysis, smell is always aquatic, for a substance is not smelled until it passes into solution in the mucous film of the nasal passages. For fishes, of course, the odors are already in solution in their watery environment.

After all, if miners can use canaries, why couldn't water works men use fish? Not only do they have the advantage of getting the smell without having to wait for it to dissolve, but

(Continued on page 60 P&R)

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(Continued from page 58 P&R)

its element is theirs. And, as there are no proper words, anyway, their inability to talk should be no great handicap. Without doubt, a fish scale better than the nose-thumb rule could be worked out, but now we understand that that development has already been obviated by a new device introduced by Evans Research of New York.

The Evans device is a mechanical sniffer made up of a series of ionization detectors in conjunction with gas chromatographs. Through its use, very fine distinctions—as between types of whisky on the breath, between natural and artificial flavors, between cigar and cigaret smoke—can be made. Said to be effective in the odor-flavor research areas and in the field of quality control, the sniffer seems a natural —that is an artificial—substitute for the nose as an instrument to monitor the effluent of water treatment plants, harmonious, nonparasitic, and not at all fishy!

Disarmament, for which we have been keeping our fingers crossed, is apparently home free—at any rate, as far as the Navy is concerned. Why else would the US Naval Supply Depot at Ogden, Utah, be accepting bids now for "261,539 lb of drinking water, packed in 276,275 cans, six can openers with each 75 cans, suitable for bomb shelters"? It is possible, of course, that these cans are being disposed of because they contain only approximately 0.94666184 lb each—that is 1 can opener to 8 lb of water—but

(Continued on page 108 P&R)

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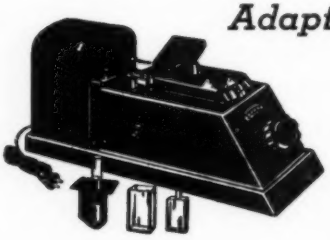

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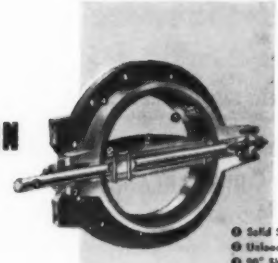
BUILT-IN  VALVE DEPENDABILITY...

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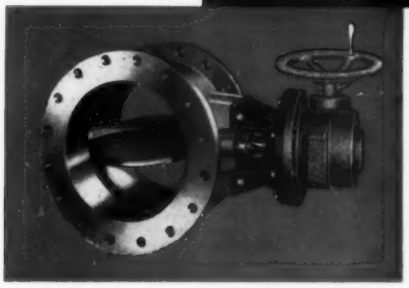

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Key: In the reference to the publication in which the abstracted article appears, 39:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, 39:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

POLLUTION CONTROL

Foaming of Liquids Containing Synthetic Detergents. G. A. Truesdale. *Wtr. & Waste Treatment J.* (London), 7:3:108 ('58). A study has been made at the Water Pollution Research Lab., Stevenage, Hertfordshire, of the relation between foaming, the type of liquid and the type and concn. of detergent present; from this study a routine method for the rapid testing of samples has been evolved. The apparatus used consisted of a 6-ft vertical glass pipe of 4 in. internal diam., fitted with a 1-in. cube diffuser and a sampling tap at the lower end. Air was blown through a 3-ft column of liquid under a pressure of 4 psi at a rate of 90 ml/min. Foam height was measured at intervals. No strict control of temp. seems to have been made—"expts. were made at about 15°C." Expts. were carried out on detergent-free synthetic sewage, tap water, filter effluent and settled sewage. A mixt. contg. equal weights of 7 proprietary household detergents was tested in the above liquids at concns. of 0.5–20 ppm as Manoxol OT (detergent concns. as Manoxol OT detd. by the Longwell and Maniece method). Typical expts. showed a linear increase in foam height with time, to a max. value. The max. height of foam and the time taken to achieve it increased with detergent concn. The tendency to foam was greatest in tap water and became progressively less as the poln. was increased; however, the proportion of detergent lost from a particular type of liquid in the production of a foam was constant for that liquid and independent of the detergent concn. These expts. also show that the amt. of detergent present in a given vol. of foam was a reasonably constant figure. The author has suggested that the constancy of this figure may be related to the amt. of detergent required to form a monomolecular layer at the air-water interface. By a rough estn. he has calcd. the area occupied by 1 detergent molecule to be 135 sq Å for Manoxol and 86 sq Å for Teepol (a secondary alkyl sulfate). These figures are of the right order. Foam production thus would be dependent on the availability of sufficient detergent in the liquid; the presence of suspended solids which may absorb detergents may account for the retention of some detergent and thus a reduction in foaming. The routine test for the examn. of the foaming tendencies of liquids measured the max. height of foam that was produced in 8 min. with a flow rate of 90 ml/min at a pressure of 4 psi. In its present form the test is suitable for comparison of the foaming properties of sewage and sewage effluent containing 0–8 ppm of surface-active material as Manoxol OT.—*BH*

Synthetic Detergents: Results of Their Degradation on Johannesburg Sewage Works and Streams. P. E. Spargo. *Pub. Health* (Johannesburg), 25:1:11 ('59). The paper opens with a review of the nature of syn. dets. and of their reported effects on sewage treatment. The concn. of anionic syn. det. in the raw sewage entering the Cydna treatment works of Johannesburg varies between 1.5 and 30 ppm, avgg. 4.6 ppm, which is about one-third of the avg. concn. in Britain. At 2 of the treatment works measurements showed that only about 5% of the detergent was removed in the primary settling tanks. At the Cydna works 10–80% (avg. 50%) of the anionic agents was removed in biol. filtration. At the same works the activated-sludge plant (presumably diffused-air system), which was producing a highly nitrified effluent, removed all the detergent; there was no foaming. One of the units at the Bruma works showed increasing foaming as nitrification decreased; foam appears at a relatively late stage of the aeration but not usually in the re-aeration

(*Continued on page 72 P&R*)

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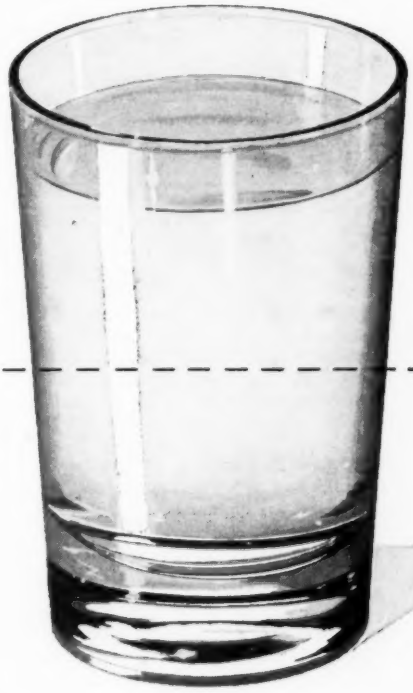

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†Comparison Studies of Diatomite and Sand Filtration by G. R. Bell, Journal American Water Works Association, September, 1956.

JOHNS-MANVILLE JM PRODUCTS

(Continued from page 70 P&R)

channel. [The author can offer no explanation of this. The phenomena he reports are probably explained by the antifoaming properties of soap, which is soon broken down, and by the higher solids concn. in the reaeration channel, which results in greater adsorption of the detergent.] Persistent foam occurs at a valve, through which the supernatant liquor from sludge digestion flows to a small pond. Sand filtration of the effluent from humus tanks reduced the residual detergent concn. as much as one-sixth, the reduction increasing with time after the last cleaning of the filter. Appreciable concns. of syn. det. have been measured in streams receiving effluent from the Johannesburg sewage treatment works and these had dropped by less than one-half after flowing 16 mi, at which point there was still appreciable foaming. Foaming occurs to a greater or less degree on all the city's works or after discharge from them.—*BH*

American Research on Detergents in Water and Sewage Treatment. H. V. Moss. *Wtr. Waste Treatment J.*, 7:253 ('59). At the annual meeting of AASGP, Inc., Jan. '59, the author presented the 4th annual report on the research program of the association designed to obtain factual information on the effect of household detergents in sewage treatment and water supplies, and including investns. on both the major ingredients of these detergents, namely the surface-active agent, usually alkyl benzene sulfonate, and the sodium polyphosphate builders. The aspects under investn. include anal. methods, the amt. and effect of the phosphate component entering water supplies, methods for removing alkyl benzene sulfonate from water supplies if this should become necessary, the effect of alkyl benzene sulfonate on the operation of sewage works, and the contamn. of ground water supplies by waste waters contg. detergents. The polyphosphate components of synthetic detergents are largely decomposed during passage through sewage works and surface streams; of the phosphate found in surface waters, such as those studied in Illinois, only a portion can be attributed to detergents, and the small concn. of phosphates remaining in the raw water causes no problem at water works. It has been shown that a large portion of the alkyl benzene sulfonate in crude sewage is degraded by biol. oxidn. during the conventional activated-sludge process, and the degree of degradation can be increased and the foaming decreased by modifications to the plant such as the "Hi-Lo" process; further expts. are still in progress. Alternative procedures investigated for removing alkyl benzene sulfonate from sewage have included adsorption on particulate matter, percolating filters, and induced frothing with subsequent surface skimming of the foam. The present concn. of alkyl benzene sulfonate in sewage (5–10 ppm) appears to have no detrimental effect on bact. growth or reduction of BOD during sewage treatment, and the foaming caused is due not only to alkyl benzene sulfonate, but to a combination of factors, which could themselves be troublesome even in the absence of detergent, including low solids concn., low rate of flow, high temp., high pH value, the type and rate of aeration, and particularly the presence of protein degradation products.—*WPA*

Three Actual Sources of Contamination of Waters Evident in the Hamburg Harbor. E. Stehr. *Gas- u. Wasserfach.* (Ger.), 100:284 ('59). Strict regulations are used to keep oil discharges at a min. in the harbor, but accidents occur. A fixed plant has been provided for the clarification of bilge water, oil tank washings, etc., as these are too complicated treatment for a mobile (barge) plant. Radioactive wastes are difficult to control; the water in the harbor is now near the permissible upper limit for radioactivity, but about 90% of this is due to K salts, which have a considerably higher tolerance. Even the overall detn. of radioactivity requires at least a day, and the identification of specific isotopes a still longer time. This makes the location of sporadic discharges of radioactive materials very difficult. Garbage dumps are also a source of possible water contamination; a new incinerator plant has been designed and installed with a view to burning some of the more difficult materials. In one case, an industry has installed an incinerator for acid resin materials, and is recovering valuable products.—*CA*

A Study of the Pollution and Self-Purification of the River Rhonel. M. Chambon. *Rev. d'Hyg. et de Med. Sociale* (Paris), 7:1:7 ('59). This paper is an extract from a report presented in '58 to the Department

(Continued on page 74 P&R)

New Coagulant Cuts Costs of Water Treatment

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High speed coagulant action of Nalco 614 is especially good news for the many municipal water treating plants now operating over rated capacity. In fact, the extremely fast action of this new coagulant promises better operating efficiency in *any* municipal system.

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Basically, Nalco 614 is a new sodium aluminate coagulant. It has excellent dry feeding characteristics due to a new manufacturing process that produces near spherical granules. It is a fast dissolving, highly soluble material.

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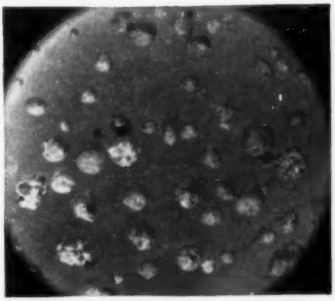

Photomicrograph of Nalco 614 particles shows one of the reasons for its excellent handling and dry feeding characteristics: spherical grains that assure free flow through conventional dry feeders.

1 ppm 614 Outperformed 10 ppm Alum according to the experience in a California municipal plant: "Nalco 614 is doing a beautiful job of both coagulation and feeding."

Quotes on Nalco 614 Handling

Here are some typical comments on Nalco 614 handling characteristics:

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"Nalco 614 flows easily, requiring no agitation and no banging on the outside of the hopper."

"It feeds as easy as rice alum. We have been able to whip all of the feeding problems that have plagued us..."

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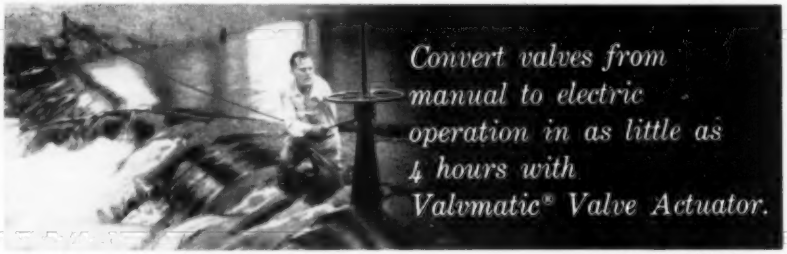
(Continued from page 72 P&R)

Com. on Water Pollution in Lyons. There is a full description with many tabd. details of the results of bacteriol. and chem. anals. of samples of water taken from the rivers Rhone and Saone at different points. In the conclusions it is mentioned that, although no previous study comparable to the one here described has been carried out, it is possible that the use of domestic and industrial detergents nowadays inhibits the natural self-purification of rivers. The main anal. results of this survey have been to show the extreme degree of poln. of these rivers at certain points. These anals. and their repetition in the future will provide a scientific basis for projects to set up future works for water purification and for sewage treatment.—*BH*

Some Considerations in the River Pollution Mechanism. T. Goda & S. Nambu. *Mem. Fac. Eng. Kyoto Univ.* (Jap.), 21:57 ('59). The characteristics of the diffusion and transportation of suspended pollutant solids in rivers, based on the results of lab. expts. and field observations, are given. In order to det. the effects of discharged sewage on the quality of the downstream water, the changing rate of the concn. of pollutant matter in a river was examd. analytically. By comparing the theoretical results with the exptl. data, some quant. relations between the discharge of sewage and the diln. factor were obtained for 2 cases: (1) where the sewage is supplied intermittently to a river and is soon distributed uniformly over the cross section, and (2) where the effluent is discharged continuously from one side. The transportation mechanism of pollutant matter from the Neya R., which is regarded as the main source of pollution for rivers and canals in Osaka City, was investigated. Practical remedies are proposed for reducing the degree of pollution in the waters of the Osaka area.—*CA*

River Pollution in Tidal Waters. T. L. Coxon. *Contract. Rec.*, 69:29:16 ('58). The problem of the present extensive poln. of the tidal reaches of the Tyne R. is dis-

(Continued on page 76 P&R)



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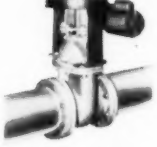

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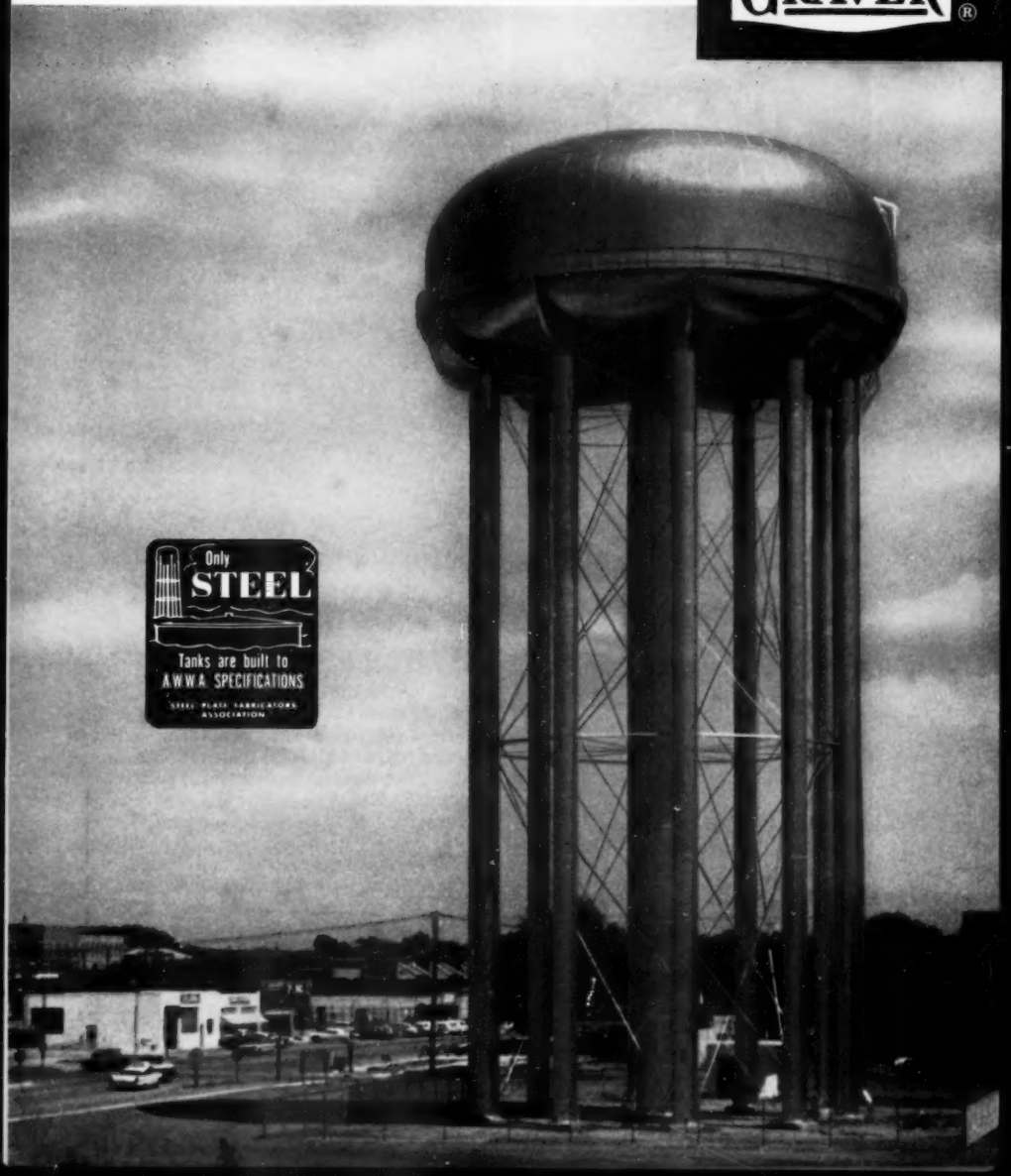

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(*Continued from page 74 P&R*)

cussed fully, and the delterious effects of this poln. on human health and fish life are emphasized. Sewage from the whole of Tyneside is pumped, untreated, straight into the river, and that, together with the discharge of trade waste waters, has resulted in the existence of anaerobic conditions in the river for 12 mi along its course. Hydrogen sulfide and gases of the methane type are given off, and the river has completely lost its capacity for self-purification. This is accentuated by dredging, which is beneficial to shipping, but is detrimental to the mixing of sea and river water, and hence to aeration. Remedial measures recommended are, that there should be no further discharge of crude sewage to the river, and that the sewage should be treated, or disposed of at sea. Disposal at sea is costly, and it may be inadequate and result in the poln. of bathing beaches. Sewage treatment is also costly, but it would give an effluent pure enough to be returned to the river, thus returning some of the water first removed; and the sludge could be used either for filling disused mines and quarries if untreated, or for fertilizer after treatment, thus offsetting the cost to some extent. The 2 projects are compared, other advantages and disadvantages of each being discussed, and the need for immediate action is stressed.—*WPA*

Slime Infestation—Literature Review. M. E. HARRISON & H. HEUKELEKIAN. *Sew. & Ind. Wastes,* 30:1278 ('58). The work of various investigators on the development of slime growths in pold. streams is reviewed and discussed. Such slime growths are usually the result of excessive development of the sheathed filamentous bacterium, *Sphaerotilus natans,* or of the aquatic fungus, *Leptomitus lacteus.* The flocs of these organisms may form a suitable habitat for a variety of other micro-organisms. *Sphaerotilus* can use as carbon sources a wide variety of organic compds., including mono- and di-saccharides, organic acids, alcohols, and amino acids. *Leptomitus* can utilize certain organic acids, but sugars appear to be unavailable. Cultural expts. show that fairly good growth of *Sphaerotilus* results when nitrate is the nitrogen supply, but for luxurious growth an organic nitrogen source, such as amino acids, is necessary. *Leptomitus* cannot grow when ammonium salts or nitrates are the sole source of nitrogen, but appears to be able

(*Continued on page 78 P&R*)

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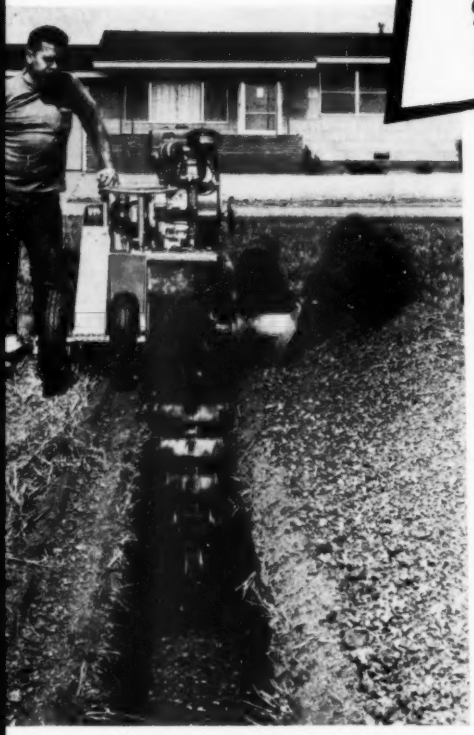

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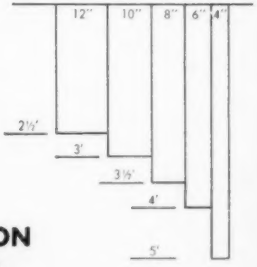

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(Continued from page 76 P&R)

to utilize ammonium salts when certain amino acids are present. *Sphaerotilus* grows best at pH values above 6.0, and can withstand alkaline conditions at least up to pH 8.0. *Leptomitus* can exist below pH 2.5, and the optimum pH range is 5.4–6.0. Both types of infestation are often more obvious during the colder months of the year, but there are indications that this is not due solely to temp., but that other factors, such as a better oxygen supply or greater accumulation because of reduced metabolic activity, may be important. Both organisms require an aerobic environment. The effect of streamflow varies, according to whether oxygen or food supply is the limiting factor. Detachment of living or dead growths may occur as a result of scouring, of cessation of food supply, of decompn. of the attached portion, or of excessive growth in relation to a given river flow. If such detached growths become reattached, a secondary area of infestation occurs.—*WPA*

Protection of Ground Water Against Pollution by Liquids. W. GAESSLER. *Wasser, Luft. u. Betrieb.* (Ger.), 2:61 ('58). The *Bundesverband der Deutschen Industrie* has drafted proposed standards for the material and construction of tanks and pipes for the storage and conveyance of liquids which, if permitted to seep into the ground, would render the ground water unuseable for supply. The proposals are based on investigations of an association representing the various interested industries and bodies. The proposals, which deal with the use of unalloyed steel for the plant, cover the construction, operation, and supervision of the plant. It is recommended that they be incorporated as soon as possible in an official standard.—*WPA*

Pollution of Water and Protection of Reserves. E. SANZOT. *Bul. Centre Belge Etude et Document. Eaux* (Liege), 40:155 ('58). In a paper presented at a meeting in Liege in '58, the author discussed the causes and nature of the poln. of surface and especially of ground water, giving various examples of the occurrence of poln. due to trade waste waters and heavy rainfall, and described legislative and tech. methods for preventing poln. of ground water.—*WPA*

Cross Section Surveys as a Method of Evaluating the Self-Purification Capacity of a Stream. T. F. WISNIEWSKI. *Tappi*, 42:67 ('59). Studies carried out jointly by the Sulphite Pulp Manufacturers' Research League and the Wisconsin Committee on Water Pollution have shown that single samples collected from carefully selected stations in clean streams or in recovery zones where the streamflow is known, may be used for evaluation of stream quality, but single samples from pold. zones are of limited value for detn. of purification capacity. For accurate evaluation of purification capacity it is necessary to carry out detailed cross section surveys which take into account the channelling of wastes and the variable distribution of flow across the stream. Results of such studies have shown that higher pollutional loadings may be permitted at lower temps.—*WPA*

Experimental Investigations on Damage to Self-Purification Processes by Poisons in Waste Waters. H. KNOEPP. *Deut. Gewaesserkundl. Mitt.* (Ger.), 2:79 ('58). Damage caused to self-purification processes by a specific poison or a complex waste water can be assessed on different biol. reactions, the bact. decompn. of organic impurities with simultaneous consumption of oxygen, and assimilation by water plants of products of mineralization with simultaneous biogenic reaeration of the water. The author describes series of expts. on the effect of Purapid plv. (technical phenyl mercuric acetate) on the decompn. of proteins, and on the effect of Purapid LO (25% phenyl mercuric oleate in neutral oily sol.), of hydroquinone, and of a complex waste water on the assimilation actvity of water plants. The assimilation tests were made by treating parallel series of samples, to one series of which algae had been added; the difference between the resid. contents of oxygen shows the effect of the added substance on assimilation. Purapid plv. in concns. of about 0.0035 mg/l reduced decompn. of proteins by more than 50%. Purapid LO giving concns. of less than 0.0009 mg/l phenyl mercuric oleate reduced assimilation by about 56%. Concns. of about 1.7 mg/l of hydroquinone reduced the assimilation activity below the "compensation point," the point at which it is outweighed by the simultaneously

(Continued on page 80 P&R)

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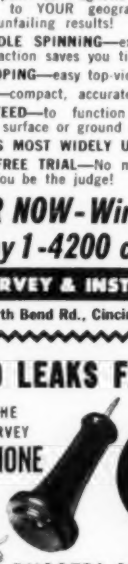
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(Continued from page 78 P&R)

proceeding respiration. Similar effects were produced by phenols, free ammonia, many products of mineral oils, and benzole derivatives. Analysis of the waste water used in the fourth series does not suggest any serious harmful effect but the assimilation test showed it to be strongly toxic with a min. harmful concn. below 1:1000. The various purposes for which the assimilation test could be used are discussed.—*WPA*

Hygienic Norms for the Amounts of the Poisonous Products (Isoprene and Dimethyldioxane) of Synthetic Isoprene-Rubber Production in the Water of Reservoirs. N. V. KLIMKINA. *Gigiena i Sanit.* (Moscow), 24:6:8 ('59). The following concns. (in mg/l) are reported for CH_2:CMeCH:CH_2 and 4,4-dimethyl-1,3-dioxane (I) resp.; detectable by odor, 0.005, 2.5; max. not affecting the sanitary regime, 30, 30; threshold for action on warm-blooded animals, 5 (0.25 mg/kg), 0.005 (0.00025 mg/kg); suggested max. in water, 0.005, 0.005. The rate of O consumption, the glycogenic ability of the liver, the conditioned reflexes, and the catalase content of the blood of rabbits were followed for periods of 4–5 mo. Stomach secretions hydrolyze I forming HCHO.—*CA*

Toxicity Index Proposed. *Chem. Eng. News*, 36:52:26 ('58). A method for detg. the "toxicity index" of chems. has been developed by Hermann for use in detg. the polg. effect of waste waters discharged to streams. The toxicity of each chem. to bacteria grown on a standard medium is detd., and the concns. of the chem. are plotted against the BOD in a toxigram. If the oxygen demand increases with increasing concn. the chem. is not toxic, but if the oxygen demand decreases the chem. is toxic. The toxicity of different chems. can be compared by comparing the TC_{50} points—the point on the curve where a specific concn. of the chem. inhibits the oxygen demand by 50%.—*WPA*

Toxicity Index for Industrial Wastes. E. R. HERMANN. *Ind. Eng. Chem.*, 51:84A ('59). A toxicity index is presented which is based on the inhibition of the BOD by the toxic agent. Both dild. sewage and synthetic culture media have been employed in

(Continued on page 84 P&R)

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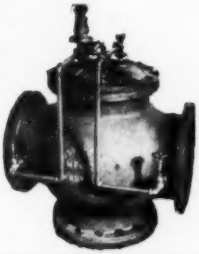

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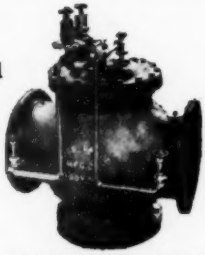

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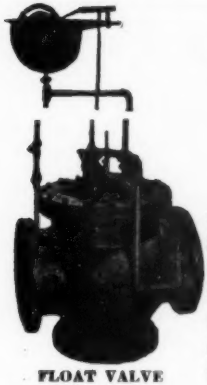

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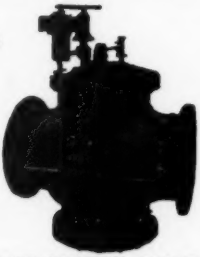

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(Continued from page 80 P&R)

the test. The toxic effects on BOD of 33 chemicals are described. Toxigrams may be obtained for the toxic agents by plotting the % available O utilized against the concn. of the toxicants semilogrithmically. The toxigrams appear to fall into 5 types. Type 1 includes the simple poisons where there is some effect at all concns., but in which the toxic effect increases with increasing dosage. In Type 2, there is no real effect on the BOD test over the range of concns. In Type 3, are included the reducing agents where the O utilization is increased as the concn. of toxicant is increased. In Type 4, the substance first exerts an O demand of its own, then, as the concn. increases, O utilization is greatly inhibited. In Type 5 there is at first no effect, than an inhibition, and then a return to no effect. This latter effect was produced only by AcH. From the toxigram, the TC_{50}, or the toxic concn. producing a 50% inhibition, can be detd.—*CA*

Problems of Practical Conduct of Stream Protection. H. KOESTER. *Gas- u. Wasserfach.* (Ger.), 99:128 ('58). A general survey is given of the many practical problems to be taken into account in measures for the protection of streams from poln.—*WPA*

Some Methods Currently Employed to Reduce River Pollution. J. B. LEY. *Commonwealth Engr.* (Australia), 45:8:62 ('58). The author outlines briefly the types of and effects of poln. and describes methods of sewage treatment and the treatment of trade waste waters, particularly radioactive waste waters. The costs of treatment are indicated. The constitution and duties of river boards are outlined. He points out the impracticability of setting up a universal standard of purification, and stresses the need for individual standards for particular rivers or stretches of rivers.—*WPA*

Effects of Suspended Matter in Waste Water. R. D. HOAK. *Munic. Utilities Mag.*, 96:5:38 ('58). In a paper presented at the Ontario Industrial Waste Conf., May '57, the author gave a report on investigations in progress to provide quant. data concerning the effects of suspended matter discharged to rivers. Several aspects of the problem of suspended matter require investigation. Flume studies have been made to devise formulas for predicting slit loads in rivers and results using Lamar's photometric method for detg. particle size of suspended solids are summarized. Data from the flume studies indicate that the amt. of settling with laminar flow is less than it is for turbulent flow.—*WPA*

The Development of Methods for Using Bio-Assays in the Control of Pulp Mill Waste Disposal. C. E. WARREN & P. DOUDOROFF. *Tappi*, 41:8:211A ('58). The authors describe expts. being carried out at Oregon State College on the bio-assay of waste waters from the manufacture of cellulose, to det. the permissible concns. of such waste waters which may be discharged to streams. Young guppies are used as the test animals; the test procedure is described in detail. The method used for detg. the "application factor," by establishing a definite relation between the results of short-term tests and the long-term effects of the waste waters on the biota of the receiving stream, is also discussed. For this purpose, use is made of artificial streams, made from wooden troughs contg. stream bottom materials and river water which is renewed continually, and various fresh-water animals and plants are introduced. The effect of adding the desired concn. of waste water to the river water can then be observed. The problem of slime growths in streams receiving pulp mill wastes is discussed; methods are being developed to study the slime production potential of waste waters from different mills. —*WPA*

The Problem of Pollution From Industrial Waste Water, With Particular Reference to Tannery Wastes. V. KUBELKA. *Rev. Tech. Inds. Cuir* (Czech.), 50:147 ('58). Author discusses the poln. of water from industries (coal, mining, chem., food, tanning, etc.) and states that it is 20–50 times more severe than that from city sewage systems. The industrial waste water may contain materials with or without the same qual. compn., and having the same or different concns. The tannery wastes are fundamentally different in comyn. and concn. at various times of the day, and their properties vary accordingly. Author suggests some ways of minimizing water poln. in industrial areas.—*CA*

(Continued on page 86 P&R)

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(Continued from page 84 P&R)

The Treatment and Disposal of Wash Water Sludge. P. W. Doe. *J. Inst. Wtr. Engrs.* (Gr. Br.), 12:409 ('58). Expts. are being carried out to find a mechanical method of dewatering sludge at the Stocks filtration plant of the Fylde Water Board where, as the result of coagulation of peaty water with aluminium sulfate, about 8,000 gal of sludge, contg. 1½-2% solids are produced each day. At present the sludge is discharged to a lagoon and after drying for 12-18 mo it is transported to a sludge tip. Expts. have already shown that it is possible and economical to dewater the sludge mechanically in circumstances where lagooning is impossible or undesirable. The process visualized for use at the Stocks plant would probably consist of 3 stages: first, sedimentation and prelim. thickening in a sedimentation tank adapted to permit prelim. stirring, producing a sludge contg. not less than 2½% solids; secondly, further thickening by slow stirring to about 6% solids; and thirdly, final dewatering by either pressing, heat treatment, or freezing. A detailed account is given of expts. on the effect of stirring. Expts. are still in progress to det. whether results obtained with exptl. equip. are applicable to full-scale plant, for tanks of various shapes and stirrers of various types, and to investigate the effects of the initial thickness and compn. of the crude sludge. An account is also given of the more important methods studied for the final dewatering including the use of freezing, filter pressing, filtration through porous ceramics, and electro-osmosis (not practicable), and, in an appendix, the various methods of sludge dewatering are compared, with reference to the operating range of sludge thickness, the economical range of the process, the properties of the endproduct and the filtrate or supernatant liquor, and the advantages and disadvantages of the methods. The conclusions of the expts. on freezing were that the time taken to freeze the sludge is critical (since quick-freezing produced little change in the colloidal nature of the sludge, whereas after slow freezing for 2 hr the solids remaining after thawing could be filtered in a few minutes); the temp. during freezing and thawing, and the duration of thawing have little effect; the sludge must be completely frozen and must remain frozen for a short period; the initial thickness of the sludge has no effect; and the phys. change which occurs during freezing is irreversible. The expts. on filter pressing were aimed at devising methods to produce a dry cake in a shorter time or to provide sloppy cakes for subsequent freezing. Filter pressing at high pressures appears to be feasible, but it would be imperative in practice to det. the most economical method of operation, particularly the optimal length of filter run. The Stocks sludge is not suitable for vacuum filtration. Using porous ceramics, the sludge could not be thickened to more than 8% solids, but the low operating costs might make the method useful as an auxiliary process. Modifications to the sedimentation tanks were also made in an attempt to increase the thickness of sludge deposited at certain points. The choice of a method for the final dewatering stage has yet to be made, and the advantages and disadvantages and the costs, of filter pressing, heat treatment, and freezing, are compared. Both heat treatment and freezing produce dried sludge in which reversion to the colloidal state cannot occur; this is an advantage in disposal by tipping since top soil can be spread on the tip and seeded or planted. In discussion, Porteous described expts. on the heat treatment of Stocks sludge; after treatment at a min. temp. of 320°F, rapid settling of the sludge occurred and the cake could be subsequently dried by filter pressing, vacuum filtration, or even on drying beds. Warburton described the equip. used in the freezing expts. A statement from Barrett and Palin included information on the freezing of alum sludge at the Harwell plant, and on the use of alum sludge in the brick-making industry, for recovery and reuse of aluminium sulfate, and for production of other aluminium compds. In a written communication, Pepper described the treatment of alum sludge at another water works. The sludge is separated from the wash water by sedimentation, occasionally with the addn. of a block of aluminium sulfate, floating in a wooden cage. The residual sludge, having a thickness varying up to 4%, is discharged to lagoons from which clear supernatant liquor and rain water are siphoned off, and the sludge reaches a thickness of about 9%. The sludge is then spread in thin layers on surrounding land, and dries in 3-4 weeks, the underlying grass growing through it.

(Continued on page 88 P&R)

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(Continued from page 86 P&R)

Sedimentation in the lagoons was retarded by high pH values, and was improved by addn. of alum and by frost.—*WPA*

Research and Experiments on the Problem of Radioactive Substances Contained in Water. H. KOEHLE. *Bul. Centre Belge Etude et Document. Eaux* (Liege), 2:40: 124 ('58). Following a general review of water-cooled reactor types, tolerance levels for radionuclides and techniques of measuring radioactivity, the author reports the results of studies he has carried out on levels of radioactivity in Rhine R. The levels averaged 0.12×10^{-7} μc/ml, of which 0.04×10^{-7} μc/ml is due to K^{40}. The levels of activity in atmospheric fallout were determined in rain and dustout was collected on vaseline-coated sheets. Data are reported for Cologne and Duesseldorf for the period Sep. 30 to Nov. 25 ('57). Weekly activity levels ranged from 6 to 660×10^{-4} μc/sq m. A plot shows the relationship between activity in rain and in the Rhine R. water. Results are reported on the degree of removal of Sr^{90}, Cs^{137}, and a mixt. (3:1) of Sr^{90} and Cs^{137} from water by chem. pptn. Depending on the hardness of the water and chem. agents used, Sr^{90} removals ranged from 58 to 97%. A removal of 5% of the Cs^{137} was removed by alum coagulation. Intermediate values were obtained for the mixt. Sr^{90} and Cs^{137}. Further studies utilizing cation, anion, and mixed-bed resins, as well as zeolite beds gave a decontamination factor in excess of 10^4.—*PHEA*

Necessary Means for the Protection of Water Supplies in the Development of the Atomic Industry. W. DROBEK. *Staedtehygiene* (Ger.), 9:6 ('58). Commission on Radioactive Substances and Water, formed by *Verein von Gas- und Wasserfachmännern*, the *Verband der deutschen Gas- und Wasserwerke*, the *Abwassertechnische Vereinigung*, and the *Gesellschaft deutscher Chemiker* (*Fachgruppe Wasserchemie*), has formulated minimum requirements for the disposal of radioactive wastes so that water, and thereby public health, may not be harmed. Author

(Continued on page 90 P&R)

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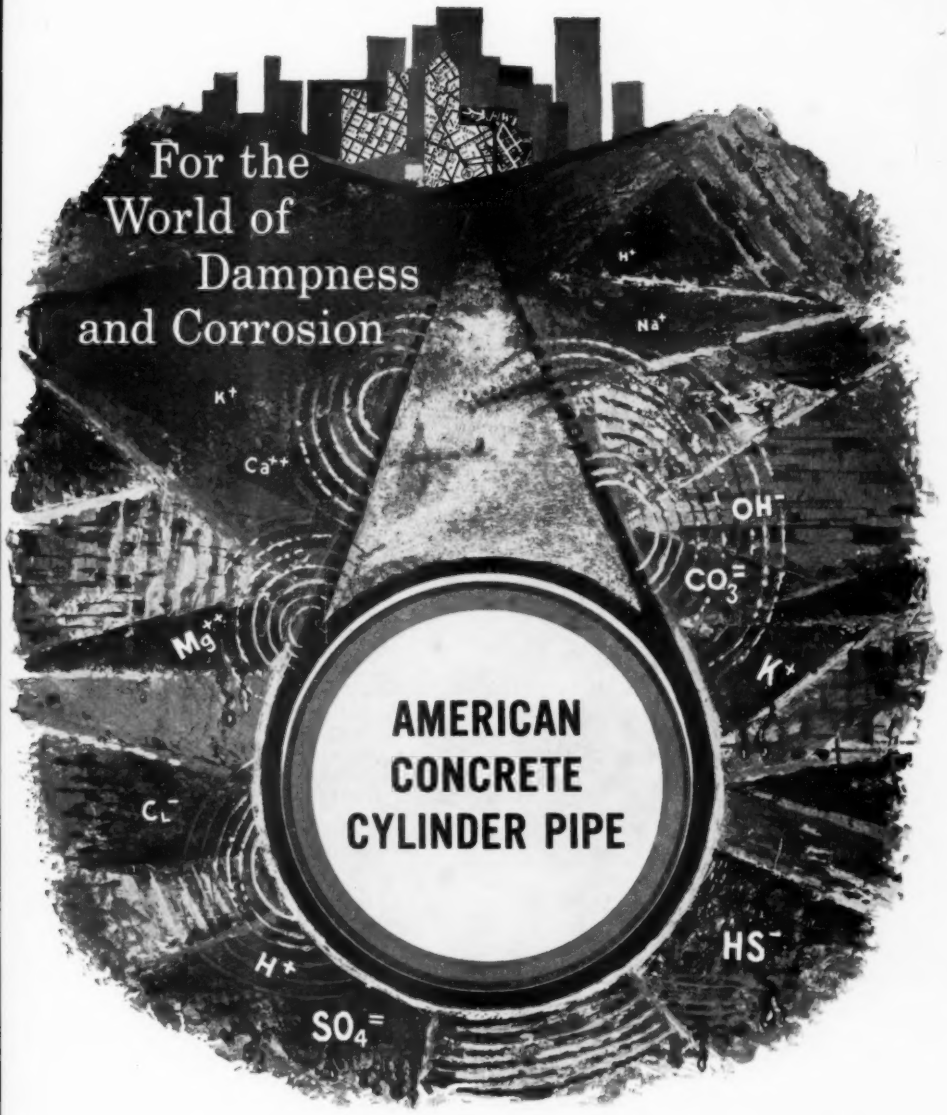

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(*Continued from page 88 P&R*)

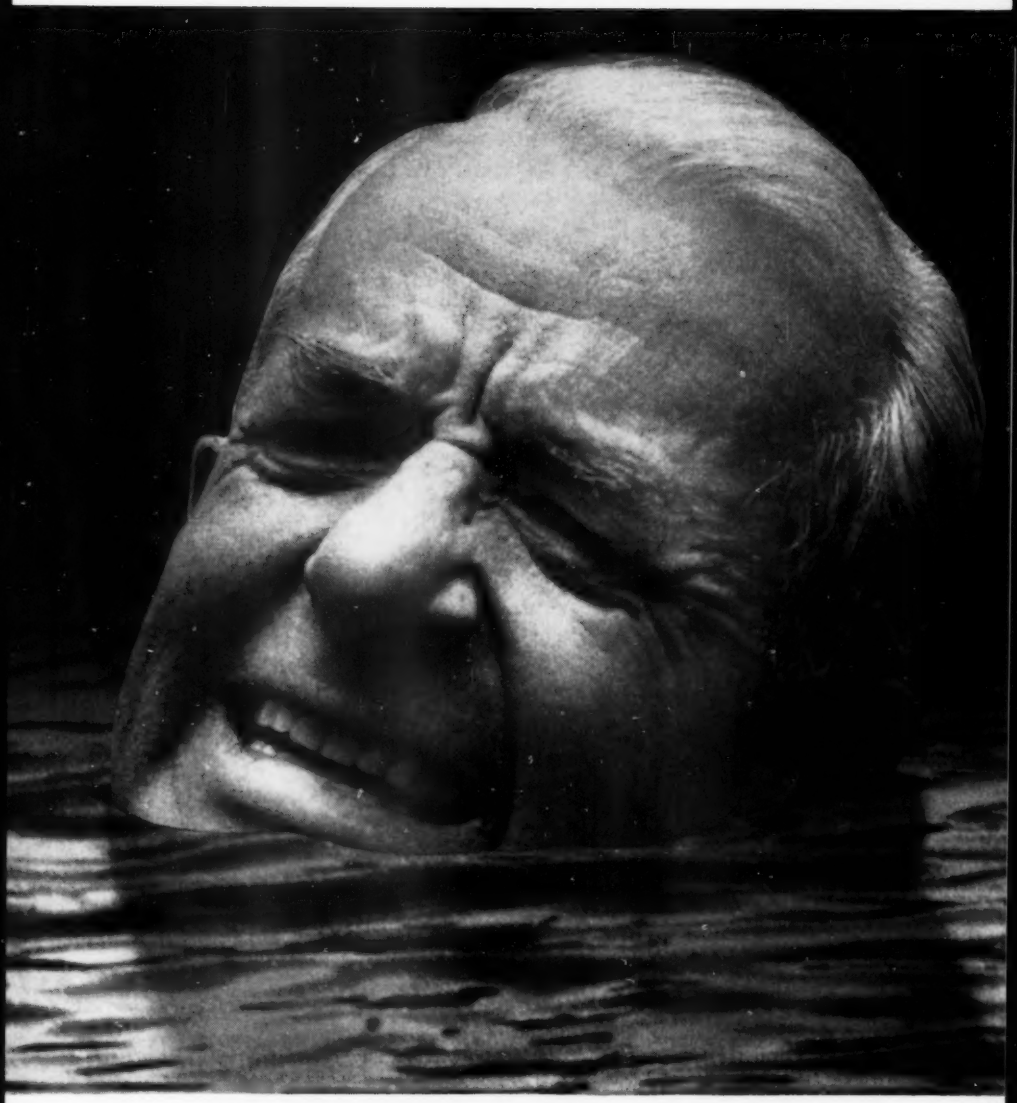
quotes these requirements, which deal with safety limits for the content of radioactive radiation and radioactive isotopes in water, choice of sites for atomic plants, methods of disposal of radioactive wastes and protection of water, soil, and air, and cooperation between water utilities and atomic industry. —*WPA*

Safe Disposal of Waste From Atomic Energy Establishments. B. A. LISTER. *Surveyor* (Lond.), 117:497 ('58). An extract from a paper presented at the Royal Society of Health's Congress at Eastbourne, Apr.–May '58. Factors to be considered in assessing amt. of radioactivity which may be safely discharged to a river are discussed with particular reference to use of water for drinking purposes; effect of biol. concn. in aquatic vegetation, in soils, and in fish; removal of activity by biol. organisms; and use of river for recreational, agricultural, and industrial purposes. Factor limiting discharges from Atomic Energy Research Establishment at Harwell, Atomic Weapons Research Establishment at Aldermaston, and Radiochemical Centre at Amersham is use of river water for drinking purposes, the 3 points of discharge being above water supply intakes. Radioactivity in effluent is divided into 4 classes and formulas are given for calcg. permissible discharge into a river, taking into account flow of river. Using Thames as an example, formula leads to present authorized max. permissible discharge from Harwell of 20 curies per mo. Waste waters at Harwell need chem. treatment before discharge. Capacity of treatment plant is 30,000 gph; efficiency for removal of alpha activity is 98% and for mixed beta activities about 80%. A new pilot plant designed to treat 5,000 gpd by sludge-blanket precipitation and ion exchange on vermiculite is operating at efficiencies of 99.8% and 95–99%, respectively. Disposal of waste waters from Windscale plutonium factory through a pipe extending for 2 mi along sea bed is discussed in relation to local conditions; a discharge of more than 5,000 curies per mo is permissible. Expts. have also been carried out to investigate probable fate of radioactive material discharged into sea off the Dorset coast from new atomic energy establishment at Winfrith Heath. Disposal of solid radioactive waste, with or without incineration, is also discussed.—*WPA*

Some Data on the Effect of Radioactive Strontium on the Processes of Self-Decontamination of Water Reservoirs. V. M. ZHOGOVA. *Med. Radiol.*, 2:6:69 ('57). Results are reported of investigations carried out under lab. conditions and aimed at discovering effect of various concns. of radioactive strontium on processes of self-purification of water reservoirs from organic contaminants. To wide glass vessels with water pold. with sewage, radioactive strontium was added in different concns. Following detns. were carried out daily over a period of 10–11 days: (1) tot. no. of colonies in 1 ml water; (2) *B. coli* titer; (3) pH; (4) *5-day* biol. oxygen requirement; (5) amt. of ammonia nitrogen; (6) nitrites; (7) nitrates. It was found that the presence of Sr^{89} and Sr^{90} in water in concns. not exceeding order of 10^{-2} c/l exerted no inhibitory effect on water microflora and on mineralization of organic substances. Sr^{90} in concns. down to 10^{-3} c/l did not affect multiplication of *B. coli* in synthetic medium at 37°C, but inhibited its multiplication to some extent during first 4 hr when concn. was 10^{-2} c/l. Sr^{90} concn. down to 10^{-3} c/l had no negative influence on viability of *B. coli* in physiol. soln. at room temp. Concns. of 1.3×10^{-1} c/l caused more rapid death of *B. coli* (75–80% during the first 24 hr), but even at such high concns. of radioactive strontium, 3–5% of bacilli remain resistant to radiation. Concns. of radioactive strontium which gain access to water and sediment in open water reservoirs by way of sewage and waste water will not exert an inhibitory effect on microflora present in water and on processes of self-purification.—*PHEA*

Magnesia Pulping Breaks Pollution Stalemate. *Chem. Eng.*, 18:60 ('58). To reduce poln. of Androscoggin R., Berlin, N.H., pulp mill of Brown Co. now employs magnesia-base pulping process, with recovery of chemicals. Waste water is concd. in a multiple-effect evaporator to give a liquor with a solids content of 55–60%. Liquor is then burned to yield a gas containing sulfur dioxide and fine suspended magnesium oxide ash. After sepn. from gas, magnesium oxide is slaked to magnesium hydroxide, and slurry is brought into contact with flue gas to absorb sulfur dioxide, forming fresh magnesium bisulfite liquor. A flow diagram of process is given.—*WPA*

(*Continued on page 92 P&R*)



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(Continued from page 90 P&R)

BOILERS AND FEEDWATER

Removal of Oxygen From Feedwater for Boiler Plants. *Gas- u. Wasserfach.* (Ger.), 99:673 ('58). When sodium sulfite is used for removing dissolved oxygen from boiler feedwater, a considerable excess is required. Sodium sulfate and some excess sodium sulfite remain in soln. and may deposit in the boiler tubes, impairing the efficiency of heat transfer. At high temps. sufur dioxide may be given off, with risk of corrosion. Hydrazine, on the other hand, is completely used up, forming water and nitrogen; at temps. over 230°C it forms ammonia and nitrogen, insuring a satisfactory degree of alky. in the water; and it reduces iron oxide on the boiler walls to magnetic iron dioxide, improving heat transfer.—*WPA*

Boiler Feedwater—Technology and Routine Analysis. R. FREIER. *Literaturber. Wasser, Abwasser, Luft & Boden* (Ger.), 7:73 ('58). In the first part of his book, which is designed to cover modern knowledge in the field of boiler feedwater, the author deals with the fundamental chemistry of water and the theories of protective layers, corrosion, and erosion. The second part deals with methods of treatment and the third with measuring and recording apparatus. Recommended processes for the chem. analysis of boiler feedwater are described in the fourth part of the book.—*WPA*

Copper Deposition During the Acid Washing of a Boiler. G. RESCH. *Mitt. Ver. Grosskesselbesitzer* (Ger.), 60:219 ('59). The intermediate reheater of a Benson boiler was washed with Na_2CO_3 soln. and then with dil. HCl until the HCl concn. reached 5–6%. Then, NaF was added. A Cu color was noted on the walls of the uncoated mixing tank and on a steel test piece. The temp. of the recirculated soln. had fallen to 40°C. Analysis indicated that the color was due to Cu. The Cu-coated tubes were cleaned with a steam-NH_3-air stream; about 1 kg of Cu was recovered. This Cu was attributed to the soln. of Cu from the scale on the tubes, which contained about 0.2% Cu (corresponding to the analysis of the tube metal). Lab. tests with a 5–6% HCl soln. contg. HF and 10–20 mg/l Cu indicated that a layer of Cu would plate out on a clean surface in 2–3 hr at 50°C, but not at 70°C. Further tests indicated that the temp. of the acid wash soln. should be maintained above 60°C at all times to avoid Cu deposition.—*CA*

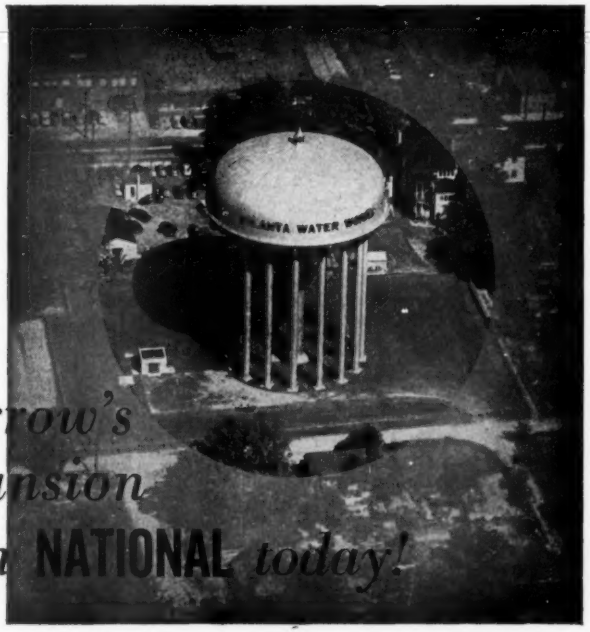
Feedwater and Boiler Water Standards in the Central Electricity Generating Board. R. L. REES & F. J. TAYLOR. *Fluid Handling*, 109:47 ('59). The standards required by the Central Electricity Generating Board for boiler feedwater and boiler water are enumerated. One standard treatment system only need be used, which can be adapted when necessary to the requirements of any individual plant. The board's requirements for the concns. of dissolved oxygen, carbon dioxide, ammonia, metals and metallic ions, sulfite and hydrazine and oil, and for the pH value, are stated, and conditions for boiler plants with natural or assisted circulation used by the board, are discussed.—*WPA*

Prevention of the Formation of Boiler Scale in Evaporators Which Operate With Water From the Caspian Sea. I. Z. MAKINSKII. *Azerbaidzhan. Neft. Khoz.* (USSR), 36:1:28 ('57). Tables are presented showing how much NaOH and Na_2CO_3 must be added to the water, depending upon the analyses for Ca, Mg, Al, Fe, and SO_4^{--}, and which steam pressures must be used in the treatment to get a nicely filtrating ppts. which is a mixt. of $MgCO_3$, $CaSO_4$ and other compds. The water, treated correctly, can be used in boilers without any corrosion risk, and the treatment is economical owing to the savings in repair work.—*CA*

Salt Damage to Boiler Metal. C. A. FARRIS JR. *Southern Power & Ind.*, 77:9:41 ('59). When water is treated in an ion exchange plant, care must be taken to prevent the NaCl used for regenerating the exchange resin being carried to the boiler. Suitable tests should be made. Photographs of boiler tubes show chloride pitting.—*CA*

Prevention of Damage to Boilers Obtained by Modern Water Treatment. E. SEYB. *Gas- u. Wasserfach.* (Ger.), 99:597 ('58). The author deals with the design and operation of plants for and the effects of treatment of boiler feedwater by lime, and by ion

(Continued on page 96 P&R)



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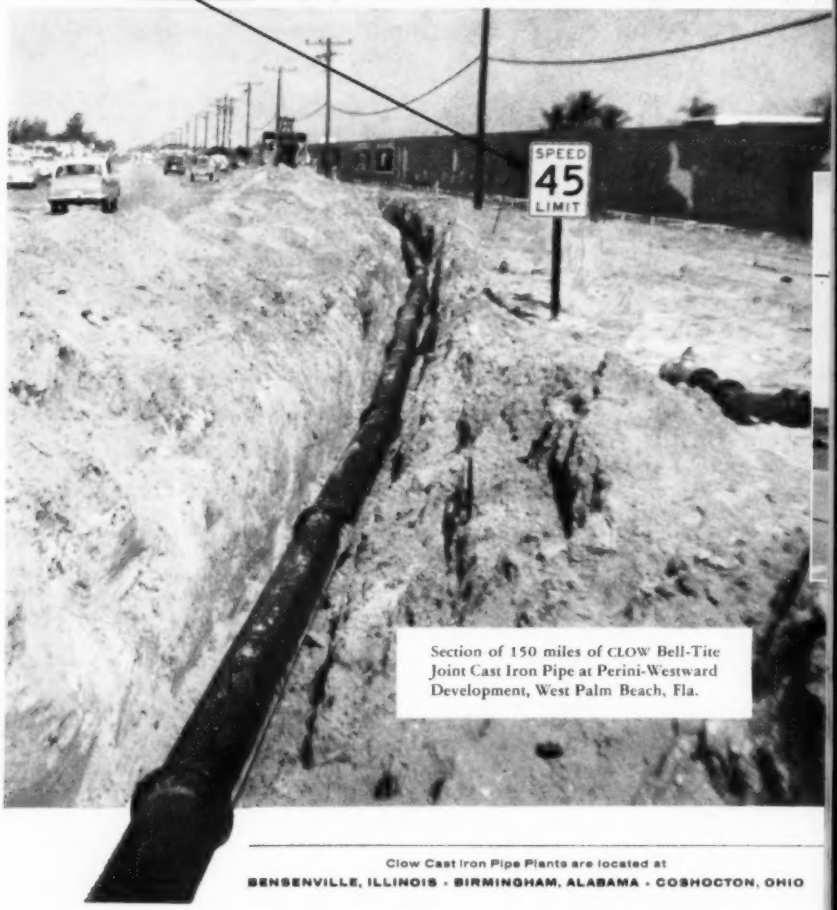

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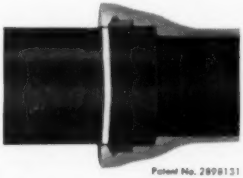

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(Continued from page 92 P&R)

exchange. Methods of treatment by both hydrogen and sodium-exchange materials in parallel, in series, and in mixed beds are described. Diagrams are given of the design of plants for the various processes.—*WPA*

The Behavior of Calcium Hydroxide and Calcium Chloride in the Tubes of a Direct-Flow Boiler. Y. F. Samoilov & O. K. Smirnov. *Teploenergetika* (USSR), 6:2:53 ('59). The soly. of Ca compds. in water vapor and their behavior during the process of superheated steam generation were studied, under controlled temp. and pressure conditions, in a lab. app. equipped with an elec. heated steam generating tube (6–15 mm in diam.) simulating the coil of a boiler. Demineralized condensate to which 2.05–11.3 mg $Ca(OH)_2$ or 4.15–35.2 mg $CaCl_2$/kg had been added, was used as feed water. Ca and Cl ions in the outgoing superheated steam condensate and in the scale formed in various sections of the tube, were detd. by trilonometric titration and by mercurometry, resp. In expts. with $Ca(OH)_2$-contg. feedwater, an abrupt drop in the Ca content of the outgoing steam was observed at approx. 470°. Thus, at a presure of 150 atm., the concn. of Ca ions decreased from 0.1 to 0.01 mg/kg. In the 480–590° range, the concn. of Ca ions in the steam remained low and practically const. The lowering of the soly. of Ca in superheated steam at about 470° indicates that, regardless of pressure, $Ca(OH)_2$ is converted to CaO within a const. temp. range. The acidity of the condensate and the alk. reaction of the scale, when steam was generated from $CaCl_2$-contg. water, can be interpreted as evidence of extensive hydrolysis of Ca salts in the steam-generating tubes, resulting in the presence of free HCl in the steam and in predominance of alk. hydrolysis products, $Ca(OH)_2$, CaO, and possibly Ca(OH)Cl, in the scale. The ratio of Ca:Cl ions in the deposits varied with the temp. of the tube sections and with the concn. of $CaCl_2$ in the feedwater. At 150 atm. and 29.2 mg $CaCl_2$/kg it was 1.1–1.4 in the zone of vaporization. In the 350–600° range and under 150, 240, and 300 atm, the concn. of Ca ions in the superheated steam was not affected by the concn. of $CaCl_2$ in the feedwater. The concn. of Cl ion, however, increased with increasing concns. of $CaCl_2$. It is concluded that the amt. of Ca carried away with the steam at temp. below 470°, is detd. by the soly. of $CaCl_2$ (and possibly, its hydrolysis products), whereas above 470°, the soly. of CaO in steam is the detg. factor.—*CA*

Treatment of Boiler Water With Sulfite or Hydrazine. R. Massart & L. Missa. *Bul. Centre Belge Etude et Document. Eaux* (Liege), 42:276 ('58). A comparison was made of Na_2SO_3 and N_2H_4 as boiler water deoxygenates. The Na_2SO_3 was added at intervals in the boiler, whereas the N_2H_4 was added continuously to the condenser. In general, Na_2SO_3 was more reactive than the N_2H_4, but the latter was advantageous when air was accidentally admitted. The pH of the vapors was less than 7 with Na_2SO_3; this compared unfavorably to a pH 9 with N_2H_4 in a Cu-surfaced system. This lowering of pH was due to entrainment of Na_2SO_3. The amt. of dissolved Fe decreased with the use of N_2H_4, but the amt. of Cu in soln. was relatively unaffected. Economically, the use of N_2H_4 was found to be superior despite higher initial chem. cost.—*CA*

Chemical Cleaning of Benson Boilers. H. G. Heitmann. *Mitt. Ver. Grosskesselbesitzer* (Ger.), 62:319 ('59). A new chem. method for cleaning boilers in power stations, especially those with forced circulation, was described. The cleaning of the circulating system was done at temps. above 100° and pH approx. 4.0. The addn. of a weighed amt. of HCl or H_2SO_4 was done in the feedwater supply piping with pressure behind the pump feeding the boiler. To protect the pump, a given amt. of 15% N_2H_4 was added to increase the pH to over 5.0. At the same time N_2H_4 served as a "carrier" of the acids through the circulating system. HF could be added to the cleaning soln. to eliminate silicic acid, and citric acid to eliminate Fe as a sol. complex. The photos of polished surfaces showed that the cleaning soln. did not affect the metallic surface of the material most often used for boilers. Eight installations of Benson boilers were cleaned by this method, and the results were discussed in more detail. Industrial analyses of installations cleaned by this method were compared with those cleaned by conventional methods, and the advantages of the former were shown. Different possibilities for cleaning boilers could be seen from the description of individual cases.—*CA*

(Continued on page 98 P&R)

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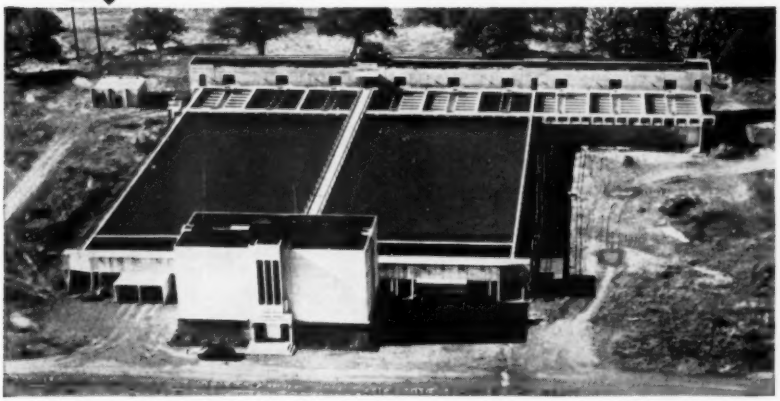

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(Continued from page 96 P&R)

Simplified Tablet Tests for Water Used in Steam Generation. A. T. PALIN. *Eng. & Boiler House Rev.*, 74:151 ('59). A series of tests for boiler water and boiler feedwater have been worked out for use with operators unskilled in chem. manipulation. With 1 or 2 exceptions, all reagents for a given test are combined together in a single tablet of standardized wt. so that the only app. required is a stoppered bottle for shaking the sample and the appropriate bottle of tablets. The general procedure consists of adding the tablets to the sample of water, 1 at a time, until the required color change is obtained. Crushing the tablets is unnecessary, as ingredients are incorporated to cause disintegration on shaking with the sample. Where necessary, the tablets contain interference suppressors and also suitable foaming agents which permit absorption of color in the foam layer, thus enabling end points to be detd. even for dirty or discolored samples. The tests themselves are based on established procedures. Although the accuracy obtained is generally quite satisfactory, a method is suggested for increasing this. Tablets are provided for pH, alky. (both methyl orange and phenolphthalein), hardness (3 tests), chloride, and sulfate.—*CA*

The Solubility of Low-Volatility Substances in High-Pressure Steam. M. A. STYRIKOVICH. *Radioisotopes Sci. Research, Proc. Intern. Conf.* (Paris), 1:411 ('58). The distribution of a no. of substances between water and steam phases depending on the presure and concn. has been studied. Distribution is largest for weak acids (silicic, boric), much smaller for chlorides and hydroxides, and still less for sulfate, silicates, carbonates, and phosphates. The soly. of NaCl, Na_2SO_4, $CaCl_2$, $CaSO_4$, $CaCO_3$, and $Ca(OH)_2$ in the system solid-steam at subcrit. pressures and in the system solid-H_2O at supercrit. parameters (to 300 atm. and 650°) has been studied. State diagrams for H_2O–SiO_2, H_2O–NaCl, H_2O–Na_2SO_4, H_2O–$CaSO_4$, including both the regions of the

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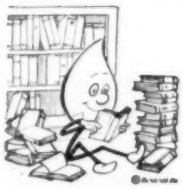

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liquid and steam phases at subcrit. and supercrit. pressures, are presented. The hydrolysis of salts by superheated steam was detected at temps. as low as 550°-600°.—*CA*

Characteristic Curves of Boilers. SACHIO YOSHIZAWA. *Netsu-Kanri* (Jap.), 11:7:16 ('59). The max. efficiency of boilers is correlated with and expressed in the functions of fuel consumption, degree of excess of air, pressure, etc. The curves (or surfaces) expressing these correlations give the most efficient conditions from simple detns.—*CA*

The Treatment of Water in Power Stations in the Netherlands. R. FEITSMA. *Bul. Centre Belge Etude et Document. Eaux* (Liege), 40:103 ('58). In a paper presented at a meeting in Liege, '58, the present situation regarding the use of water in electric power stations in the Neth. was discussed, with particular reference to the chem. characteristics and treatment of the water, including condensate, boiler feedwater, boiler water, vapor, and makeup water. Special attention is given to the effect of increased presures in the boiler system on the chem. requirements of the water, and the limiting concns. of constituents are given for various ranges of pressure. The standards given are sufficient to prevent corrosion and deposition in the turbines. The treatment of the makeup water is discussed; this requires complete removal of hardness and reduction of the carbon dioxide content. In the Neth. most power stations still employ the distillation method for treatment of makeup water, but ion-exchange methods are being adopted. These methods are discussed, including the Spiractor method involving cold lime treatment, followed by sand filtration and treatment in an ion-exchange unit operating on the sodium cycle. Another method involves hot lime treatment followed by a similar ion-exchange treatment. The lime treatment can be replaced by an ion-exchange unit operating on the hydrogen cycle, followed by a column for removal of carbon dioxide. Problems in the operation of the ion-exchange units and methods for their regeneration are also considered.—*WPA*

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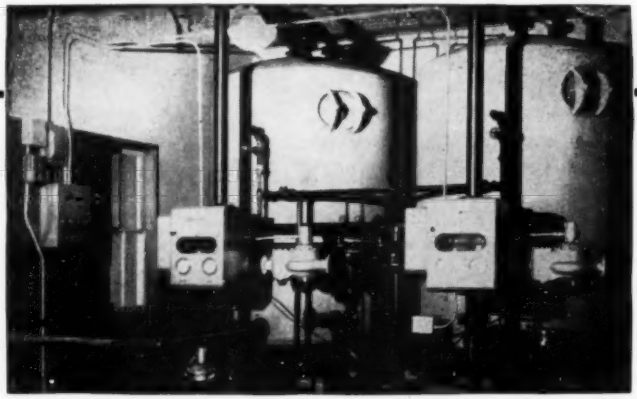

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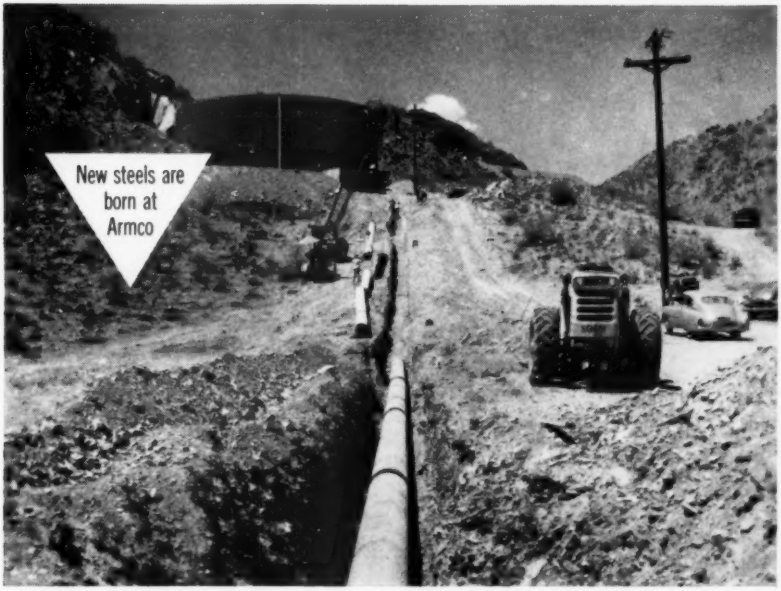

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HYDROLOGY, CONSERVATION, AND IRRIGATION

Calculation of Water Demands for Irrigation. L. SINE & J. CALEMBERT. *Bul. Centre Belge Etude et Document. Eaux* (Liege), 40:89 ('58). In a paper presented at a meeting in Liege, a scheme for calcg. the agricultural water demand was presented in tabular form and discussed. It is based on measurement or calcn. of the potential evapotranspiration of a crop, the difference between this value and the rainfall being the water deficiency or the max. need for irrigation. The difference between the max. irrigation demand and the actual demand is also discussed, taking into account the ability of the soil to resist dry periods. The interpretation of the results obtained is discussed for two particular cases in Belgium in '57, namely on the clay soil near Gembloux and on rocky land in Famenne.—*WPA*

The Turbulent Boundary Layer in a Conical Diffuser. H. R. FRASER. *Proc. ASCE*, 84:HY3: Paper No. 1684 ('58). The author discusses the development of an axisymmetric boundary layer in the conical diffuser, and proposes a simple direct method for predicting the behavior of a turbulent boundary layer in a smooth-walled diffuser, based on the analysis of the boundary layer in 2 regions, and involving only the soln. of algebraic eqs. The results of expts. to confirm the applicability of the method for boundary layer calcns. are given in tables. —*WPA*

A Study of Non-Steady Ground-Water Flow With Special Reference to a Reservoir Coefficient. D. A. LEUR. *Ingenieur, 's-Grav.* (Neth.), 70:B87 ('58). The discharge from a relatively flat aluvial or diluvial area where no surface runoff occurs can be attributed to the outflow of ground water into the channels of a drainage system. This outflow decreases the reservoir of phreatic ground water which is replenished by vertical percolation following precipitation. A method has been developed for the estimation of this nonsteady flow in a deep homogeneous soil, using a reservoir coefficient, which comprises the soil factors and the distance between drainage channels, and a dimensionless diagram showing the increase of ground-water outflow during a steady vertical percolation into the saturated zone.—*WPA*

Hydrological Research in the Netherlands —II. Geoelectrical Investigations. A. VOLKER. *Ingenieur, 's-Grav.* (Neth.), 70: B126 ('58). The geoelectrical resistivity method for examining underground strata is described, and its application to geo-hydrological investigations is discussed, with particular reference to research being carried out in the Neth.—*WPA*

Measurement of Flow—Channels With Jumps. J. W. HORNER. *Tech. de l'Eau*, 11:129:29 ('57). After a brief historical survey of the hydraulic aspects of measurement of flow in open channels, meters of the orifice, overflow, and venturi types are discussed. Special consideration is given to the use of hydraulic jumps. The advantages of this method are listed and various forms of channel are described and shown diagrammatically including those with rectangular, triangular, trapezoidal, and parabolic profiles.—*WPA*

Weirs for Flow Measurement in Open Channels. F. V. ENGEL & W. STAINSBY. *Wtr. & Wtr. Eng.*, 62:291 ('58). In continuation of a review on the measurement of flow in open channels by means of weirs, the authors discuss the limits of free discharging conditions and the accuracy of flow measurement over weirs. In an appendix, area ratios are given for use in weir design calcns.—*WPA*

USPHS Studies on the Use of Hexadecanol in Reservoir Evaporation Reduction. B. B. BERGER. *Southwest Water Works J.*, 39:22 ('58). The USPHS is cooperating with the Bureau of Reclamation and other agencies in studies on reducing evapn. from water surfaces by use of monomolecular films. Immediate interest of USPHS is directed to following: toxicity potential for humans of materials proposed for such use, toxicity for fish, effect on water treatment processes and on treated-water quality, and resistance of these materials to microbiol attack. Toxicological evaluation indicates that hexacdecanol, material most often considered for use in formation of monomolecu-

(Continued on page 104 P&R)

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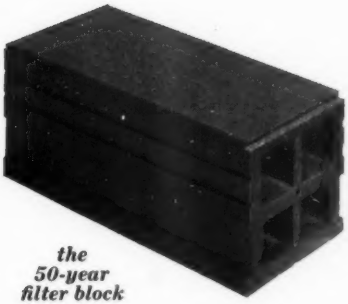

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(Continued from page 102 P&R)

lar films, may be considered nontoxic for humans when used in manner and concn. proposed. Fish appear to be able to withstand much higher concen. of hexadecanol than would be used in reservoirs. No damage to drinking water supplies and treatment processes was observed in lab. investigations. Hexadecanol, when applied in solid form, such as flakes or pellets, was attacked by microorganisms with consumption of material and its encapsulation by cellular material and detritis. It was concluded that such consumption would be signif. factor in economics of use of this material. It also appeared that capsule formed would be practical physical barrier to the free spread of the hexadecanol. Observations were based on lab. studies. Extension of lab. studies to field would be desirable to establish the validity of these observations. The USPHS is interested in continuing its joint study with other agencies in detg. practical value of conserving water by this procedure.—*PHEA*

On Evaporation From Wind-Swept Surfaces. K. J. MYSELS. *Science*, 129:38 ('59). Evapn. from water is analyzed in terms of resistances and driving forces for the coupled flows of vapor and heat. The conditions and assumptions under which all resistances can be detd. independently are discussed, and prelim. expts. on evapn. from wind-swept surfaces are reported. The effect of a monomolecular layer of cetyl alcohol on the transport of vapor was measured on a wind-swept surface. The film had no perceptible effect on the thermal resistance of air and did not seem to affect the rate of evapn. under the conditions of these small-scale expts.—*WPA*

CORROSION

Modern Theory of Corrosion and Present-Day Solutions. M. POURBAIX & F. VANDERVELDEN. *Rappt. Tech.* (Neth.), 80:2 ('59). Theory of corrosion of metals and alloys in the presence of H_2O and aq. solns. is

(Continued on page 105 P&R)

(Continued from page 104 P&R)

presented; it is based on thermodynamics and electrochem. kinetics. A method is described for detg. if, when, and why a metal or alloy can be corroded by an ad. soln. or a moist material.—*CA*

Corrosion Control Practices in the Wilmington Waterflood Operation. C. H. JONES JR. *Corrosion*, 15:99 ('59). Data are given on the method of well completion, vol. of water injected, and types of pumps and lines used in the Wilmington, Calif., waterflood operation. The method of testing inhibitors and some of the results with 3 org. amine-type inhibitors are given. Research is continuing on the use of noncorrosive materials in the system where possible. However, steel casing will probably be required in the injection wells; this will necessitate continued use of the inhibitors.—*CA*

Protection Against Corrosion in the Boiler Room. P. VAN DONGEN TORMAN. *Metalen*, 11:282 ('56); *Chem. Zentr.*, 129:1948 ('58). A protection of the boiler against corrosion

(Continued on page 106 P&R)

CEMCOTE—cement mortar lined & coated steel water pipe

TARCOTE—cement mortar lined & coal tar enamel wrapped steel water pipe

TARSPUN—coal tar enamel lined & wrapped steel water pipe

steelcor decision

WRAPCOTE—cement mortar lined & asphalt wrapped steel water pipe

Which is best?

Seldom is a decision more critical and seldom is a choice more necessary than in selecting the proper water line to do the job. There is really only one long range measurement to follow—*performance cost.*

Performance cost is not so much considered with initial outlay as it is with the relation of performance to cost over time under varying conditions, standard as well as emergency. And when performance cost is the measure—steel water pipe is your only choice.

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Southern's line of STEELCOR products include such cement mortar lined pipe as CEMCOTE (cement coating), WRAPCOTE (asphalt wrapped), and TARCOTE (coal tar enamel wrapped), to meet your every economic and performance need. Call us for complete information.

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(Continued from page 105 P&R)

is possible by alkalizing the boiler water in dependence upon the boiler pressure and by binding the O by Na_2SO_3, or hydrazine; the condensate ducts can be protected by binding of the CO_2 by NH_3 or by amines. —*CA*

Corrosion in Sour-Water Strippers. J. F. MASON JR. & C. M. SCHILLMOLLER. *Corrosion*, 15:358t ('59). Effluents contg. sulfides in appreciable concn. must be processed before discharge. The stripping method is the most generally applied process and is effective in releasing about 80-95% of the sulfides contained in foul water. Where a max. of 1 ppm of sulfide is permitted, the tower feed must 1st be neutralized to a pH of 6.3-7.3 with H_2S, converting Na_2S and K_2S to sulfates and H_2S. Steam is generally used as the stripping medium (though gases can be used) and is admitted to the base of the tower. The foul water is admitted to an upper part of the tower. Sulfide-free water is taken from the base of the tower; H_2O vapor and H_2S from the top of the tower are passed through a condenser, thus sepg. the H_2S, which is sent to the odor-abatement or S plant. The condensed water is returned to the tower feed. Corrosion problems are encountered with the condenser and upper part of the tower. For the overhead condenser, alloy materials such as Al, Monel, and Type 316 stainless steel have effectively eliminated the main corrosion products. The metal to be used must be chosen for the specific corrosive conditions; these vary greatly. Corrosion inhibitors, gunite and alloy lining, have proved generally satisfactory in protecting the stripping column. The standard material of construction is C steel. By properly conducting the stripping operation and control of the pH of the sour water feed, by avoiding high temps. and pressure, O, velocity effects, and impingement, and by proper metal choice for the condenser, good performance can be achieved.—*CA*

Influence of Bacteria on Corrosion of Stainless Steel in Small Openings. L. A. ROZENBERG; I. B. ULANOVSKII; & Y. M. KOROVIN. *Proc. Acad. Sci. USSR*, 125: 909 ('59). The presence of bacteria (*Desulfobibrio desulfuricans, Leptothriix discophora, Pseudomonas fluorescens,* and *Bacillus cereus* var. *mycoides*) on the surface of stainless steel in sea water was studied in respect to corrosion of the metal. When the plate of the steel operates as an anode, small cracks or openings in the metal into which the bacteria penetrate show slight propagation of the organisms owing to lowered pH, but these act strongly in the development of galvanic action between metallic parts after which bacterial growth rises and corrosion is stimulated.—*CA*

OTHER ARTICLES NOTED

Recent articles of interest appearing in periodicals of the water supply field are listed below.

"Shock Treatment Revives Wells." J. B. KELLY; C. R. JENSEN; & E. H. GRAS. *Wtr. Wks. Eng.*, 113:118 (1960).

"Nomograph for Equivalent Lengths of Pipe." ANNABEL TONG. *Wtr. & Sew. Wks.*, 107:80 (1960).

"How Diatomite Water Filters Are Performing." H. N. ARMBRUST. *Am. City*, 75:4:155 (Apr. 1960).

BIG FIVE IN PUBLIC WORKS
PALMER SURFACE WASH SYSTEMS
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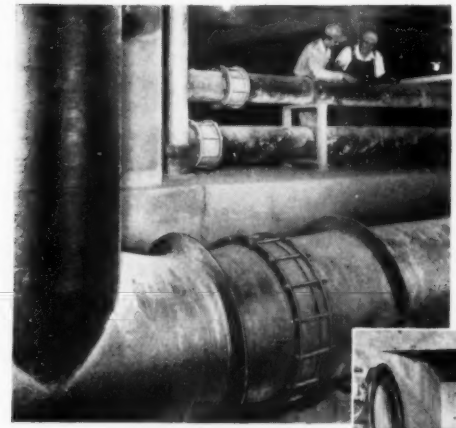
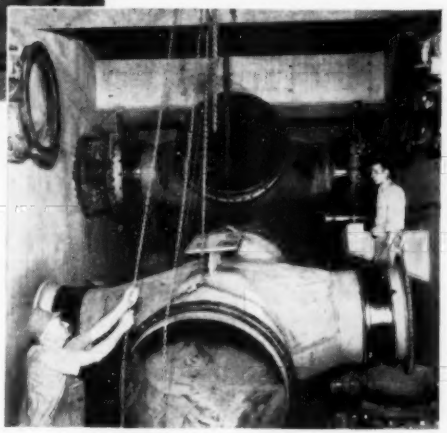


Always the easy way...

The 8-inch, 10-inch and 30-inch Dresser-Coupled lines illustrated here are part of the system used in servicing the Clague Road's advanced rapid-sand type filters.



often the only way!

This battery of steel crosses is in the new Clague Road Filtration Plant, designed by Havens and Emerson, Cleveland, Ohio. The Plant will carry a normal flow of 50-million gpd. Contractor: Hunkin-Conkey Construction Company.

Dresser® Couplings provide the essential leeway for bolting up cross flanges to valves in tight spots. They'll take deviation caused by settling concrete and remain bottle-tight... permanently! Dresser's vibration-proof properties protect valves and other expensive equipment, and protect the pipelines, too. With a Dresser Coupling, two man-minutes per bolt gives you a permanent, leak-proof joint that absorbs expansion-contraction movement, keeps maintenance problems to a minimum, and makes repairs easier if and when they do become necessary. For a free copy of "Dresser Couplings for Filtration Plant Piping" and the Dresser Sewage Treatment Plants booklet, write to Dresser Manufacturing Division, Bradford, Pennsylvania.

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Chicago
Houston
New York
S. San Francisco
Toronto & Calgary

DRESSER
MANUFACTURING DIVISION

ONE OF THE DRESSER INDUSTRIES

(Continued from page 60 P&R)

we prefer to believe that the commanding officer at Ogden really has some hot scuttlebut and has decided to unload his $22,102 inventory while he can still get more than a nickel a ton for it.

John E. Vogt was recently named director of the division of engineering of the Michigan Department of Health, at Lansing. Formerly assistant to the director, he succeeds Willard F. Shephard, who retired in January after 39 years of service with the department.

The paper cup has grown up until now a full-size pitcher is being marketed by the Dixie Cup Div. of American Can Co. Built on the order of a large paper cup with a lid, the pitcher has a tab that opens for pouring and may be reclosed to protect the contents from pollution. In Dixie's mind, no doubt, in developing this sanitary pitcher were the recent revelations concerning the spread of streptococcal infections in hospitals through the use of unsterilized water pitchers. This way safe water can be packaged in a disposable wrapper.

Riding the crest of whatever public interest has been aroused by recent scare stories on public water supply have been representatives of at least two waterborn businesses:

Thus, from the Basswood Springs Water Co. of Kansas City, Mo., we have a broadside entitled "I'm afraid of tap water! by A. J. Stephens" (president of the company) printed on the reverse of the advertisement of the *Good Housekeeping* article, "Danger in Your Drinking Water." "You would be afraid of tap water, too, if you knew the facts," says Stephens. "That's a bold statement. I would not make it if I were not sure of my ground." And the ground provided is some out-of-context information and quotes from the USPHS and the St. Louis County Water Co. regarding Kansas and Missouri river pollution. And erected on that ground is a pitch for drinking "a natural mineral-spring water . . . NOT chlorinated . . . NOT medicated . . . pasteurized just like milk and sealed in sterilized bottles. *Safe for even baby's delicate health.*" The price? Only 35 cents per ½-gal bottle or $1.98 per case of six ½-gal bottles, plus only $5 per month for a cooler.

Thus, from the Servisoft Soft Water Service of Wheeling, W.Va., we have a copy of a notice to Servisoft users, which says:

> Dr. C. Calmon, a leading chemist and scientist of the water research and conditioning industry has given us his DEFINITE ASSURANCE that the positive elements of radio activity are removed from Ohio River drinking water by the use of Servisoft Soft Water Service. Our softening unit will remove practically all the important radio-active isotopes, especially those of strontium, barium, and the rare earths caused by any atomic waste dumped into the Ohio River.

And from the Wheeling *News-Register* we have a copy of a supporting story

(Continued on page 110 P&R)

Pipe being primed at coating yard specially set up by Koppers Contract Coating Department for a large water supply project.

3/32" MAKES ALL THE DIFFERENCE

Steel water pipe will last much longer underground with the armor-like protection which a 3/32" coating of Bitumastic 70-B AWWA Enamel gives it. This corrosion-preventive coating is vital to the long-life of water lines.

Bitumastic Enamel has helped steel water lines set high flow capacity records of 40 years and more. Proven performance is one reason why so many water supply engineers are specifying steel pipe, lined and coated with Bitumastic 70-B AWWA Enamel, for their projects today. A lining of this enamel gives a uniformly smooth inside surface that has proved to have the highest flow coefficient available.

You can obtain more information about the economies of Bitumastic 70-B enameled steel pipe from Koppers Company, Inc., Tar Products Division, Dept. 110H, Pittsburgh 19, Pennsylvania.

KOPPERS

ONLY KOPPERS MAKES

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REG. U. S. PAT. OFF.

ENAMELS

(Continued from page 108 P&R)

under the headline: "Water Softener Units Remove Radioactive Calcium: Valley Youths Face Bone Cancer From River Waste."

Thus, from Grand Rapids, Mich., we have news of another home water softener salesman whose pitch has been "unless a family installs a water softening system, the household's chance of contracting poliomyelitis is greatly increased."

Give us Servisoftened Basswood Springs Water every time!

Armco Steel Corp. has elected Ralph L. Gray as chairman of the board. He has been succeeded as president by Logan T. Johnston, formerly executive vice-president.

Philip F. Walsh has been named president of Southern California Water Co., succeeding C. P. Harnish, who has retired. Harnish will remain on the company's board of directors and act as special consultant. The new president has been with the company since 1939, serving most recently as operating vice-president.

N. M. deJarnette has retired as associate director of the Water Quality Div., Georgia Dept. of Public Health, and has joined the consulting engineer firm of Robert & Co., Assocs., Atlanta. He will continue to serve AWWA as secretary of the Southeastern Section.

Walter J. Blair has been appointed vertical pump product sales manager by Peerless Pump, Hydrodynamics Div., Food Machinery & Chemical Corp. He has been with Peerless since 1949.

R. Henry Seelaus is the new vice-president—finance of Fischer & Porter Co., Warminster, Pa.

John S. Longwell, consulting engineer of Oakland, Calif., died on Mar. 25, 1960. A member of AWWA since 1931, he served as national director from the California Section in 1942–45 and was nominated to receive the Fuller Award in 1953.

Employment Information

Classified ads will be accepted only for "Positions Available" or "Position Wanted." Rate: $1.50 per line (minimum $5.00), payable before publication. Deadline for ad copy: first of month prior to month of publication desired. To place ad, obtain "Classified Ad Authorization Form" from: Classified Ad Dept., Journal American Water Works Assn., 2 Park Ave., New York 16, N.Y.

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UTILITY DIRECTOR

Wanted by City of Ashland, Ky.
Salary—$7,500–$9,500 per year.
Qualifications: Degree in civil engineering; registered professional engineer; at least five years' experience at the administrative level in a municipal water utility. Address application to City Manager, Ashland, Ky.

ASSISTANT MANAGER—Man with experience in the water business to train for District Management position. An excellent opportunity to become associated with an expanding water authority in one of the fastest growing counties in the country. Salary commensurate with experience and education. Interview will be arranged on the basis of resume submitted. Write:

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Oakdale, Long Island, New York

SANITARY ENGINEER

Excellent opportunity for engineer having a minimum of 5 years' experience, with emphasis on sewage treatment plant design and preferably with B.S. or M.S. in C.E. Salary open.

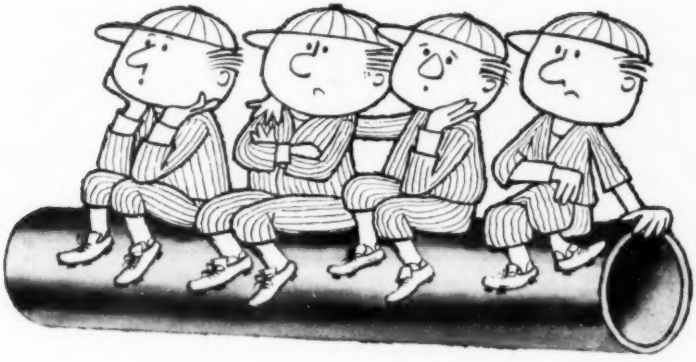
CIVIL ENGINEERS

Experienced in sanitary or hydraulic engineering.

STRUCTURAL DESIGNER

Experienced in design of concrete buildings and structures. Work in downtown Los Angeles.

James M. Montgomery, Consulting Engineers, Inc.
535 E. Walnut, Pasadena, Calif.



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Long Life	100 Years or more	?
Bursting Pressure	2,988 psi	746 psi
Bursting Tensile	25,880 psi	3,430 psi
Impact Resistance	234 ft. lbs.	60 ft. lbs.
Beam Loads (12-foot span)	20,790 pounds	3,060 pounds
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Water Absorption	None	9.8% of weight after 24-hour submersion
Tight Joints	Wide selection for liquid or gas service	Limited selection for water service
Inside Diameter	6.14"	5.85"

Pipe tested were 6" Class 150.

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(See Professional Services)

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Meet AWWA specifications

White or tinted blue • Dry and free-flowing
Minimum of storage space • Available in bags and drums
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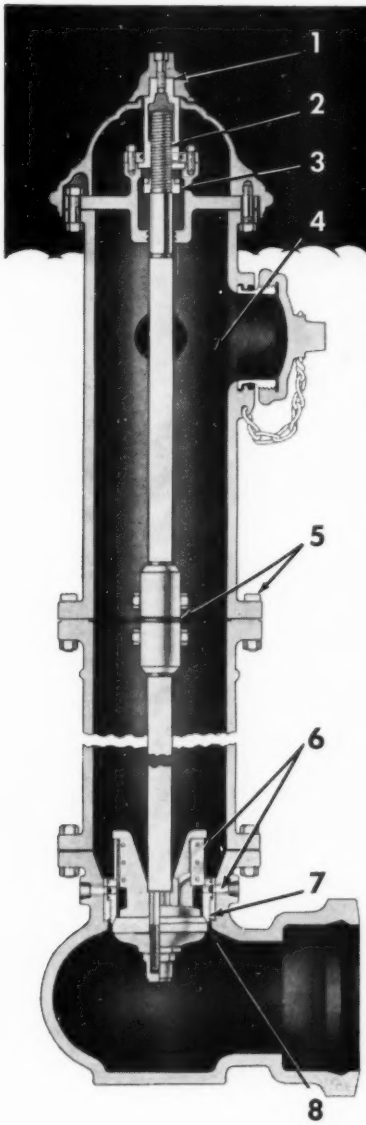

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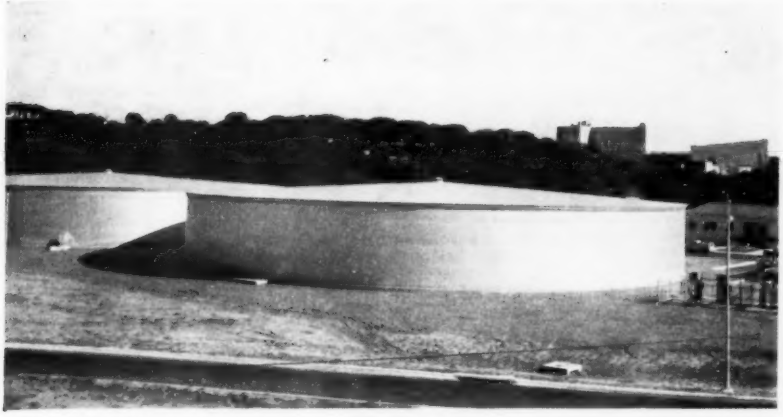

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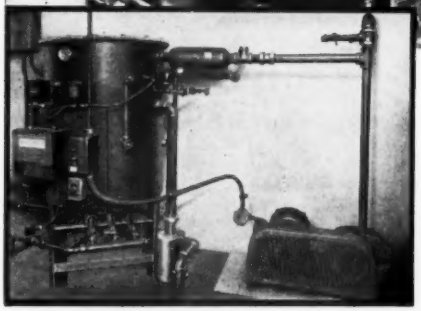

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